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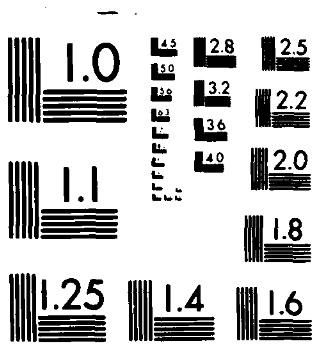

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FINAL REPORT

EVALUATION OF THE PRESENT NAVIGATION SYSTEM

PREPARED FOR THE

U.S. ARMY CORPS OF ENGINEERS
INSTITUTE FOR WATER RESOURCES
WATER RESOURCES SUPPORT CENTER
KINGMAN BUILDING
FORT BELVOIR, VIRGINIA

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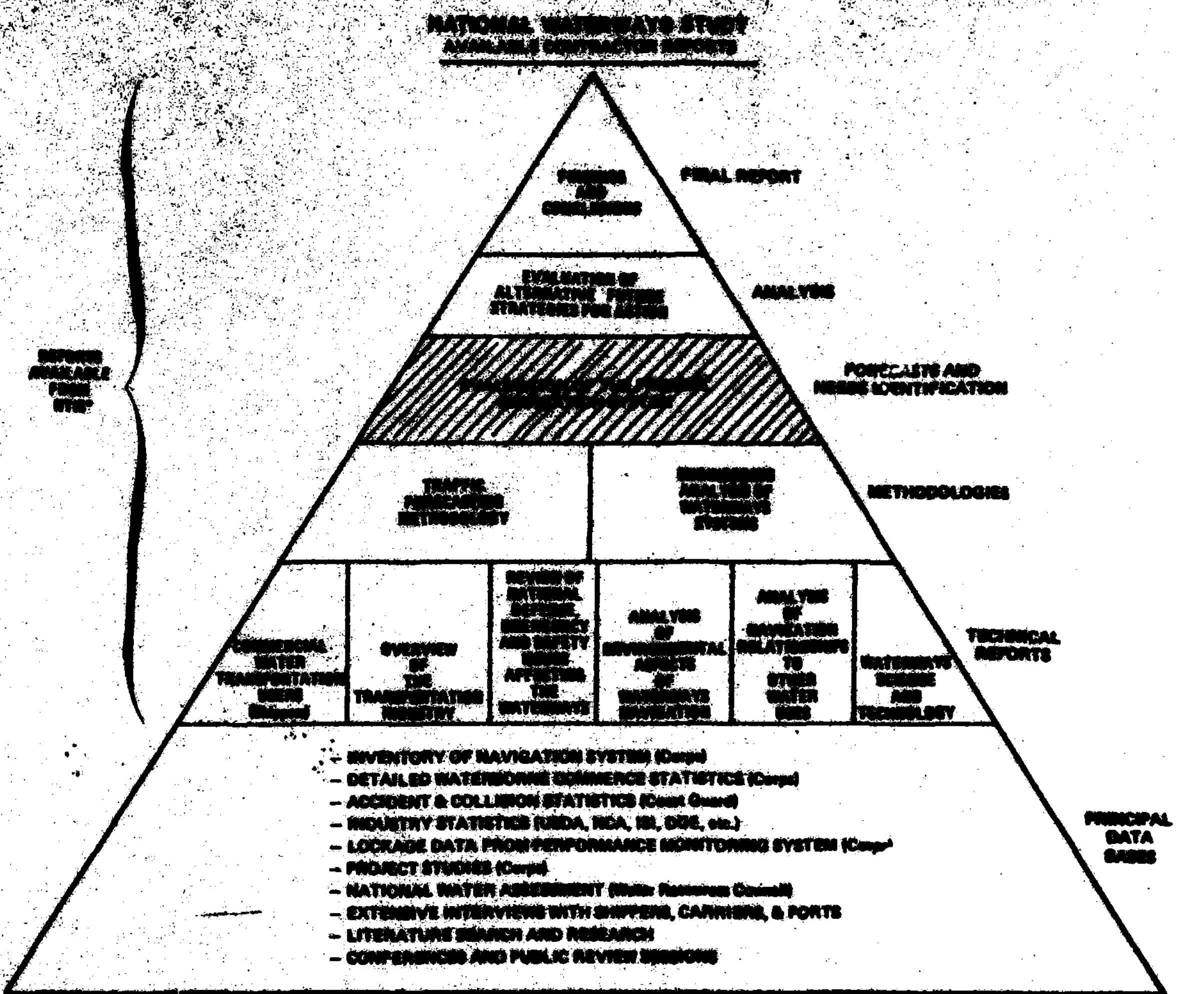
NATIONAL WATERWAYS STUDY
FINAL REPORT
ANALYSIS
FORECASTS AND NEEDS IDENTIFICATION
METHODOLOGIES
TECHNICAL REPORTS
PRINCIPAL DATA BASES
OVERVIEW OF THE TRANSPORTATION INDUSTRY
– INVENTORY OF NAVIGATION SYSTEM (Corps)
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– CONFERENCES AND PUBLIC REVIEW SESSIONS

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This report, Evaluation of the Present Navigation System, is a key integration task of the National Waterways Study. Its purpose is to evaluate the capability of the present waterway system to handle current and projected waterborne commodity flows. Evaluation of the present waterway system is based on four scenarios of future waterborne commodity flow projections and several sensitivity analyses. Earlier reports of the National Waterways Study provided forecasts of potential future use of the waterways and estimates of waterway capability. This report involves determining water transportation needs by comparing forecasts of present and projected water transportation use with estimates of the capability of the waterway system. This report presents findings regarding the ability of the present waterway system to handle current and projected waterbrone commodity flows.

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THIS REPORT IS PART OF THE NATIONAL WATERWAYS STUDY AUTHORIZED BY CONGRESS IN SECTION 158 OF THE WATER RESOURCES DEVELOPMENT ACT OF 1976 (PUBLIC LAW 94-587). THE STUDY WAS CONDUCTED BY THE US ARMY ENGINEER INSTITUTE FOR WATER RESOURCES FOR THE CHIEF OF ENGINEERS ACTING FOR THE SECRETARY OF THE ARMY.

NATIONAL WATERWAYS STUDY

EVALUATION OF THE PRESENT NAVIGATION SYSTEM

PREFACE

This report is one of eleven technical reports provided to the Corps of Engineers in support of the National Waterways Study by A. T. Kearney, Inc. and its subcontractors. This set of reports contains all significant findings and conclusions from the contractor effort over more than two years.

A. T. Kearney, Inc. (Management Consultants) was the prime contractor to the Institute for Water Resources of the United States Army Corps of Engineers for the National Waterways Study. Kearney was supported by two subcontractors: Data Resources, Inc. (economics and forecasting) and Louis Berger & Associates (waterway and environmental engineering).

The purpose of the contractor effort has been to professionally and evenhandedly analyze potential alternative strategies for the management of the nation's waterways through the year 2000. The purpose of the National Waterways Study is to provide the basis for policy recommendations by the Secretary of the Army and for the formulation of national waterways policy by Congress.

This report forms part of the base of technical research conducted for this study. The purpose of this report was to evaluate the capability of the present waterway system to handle current and projected waterborne commodity flows. The results of this analysis were reviewed at public meetings held throughout the country. Comments and suggestions from the public were incorporated.

This is deliverable under Contract DACW 72-79-C-0003. It represents the output to satisfy the requirements for the deliverable in the Statement of Work. This report constitutes the single requirement of this Project Element, completed by A. T. Kearney, Inc. and its primary subcontractors, Data Resources, Inc. and Louis Berger and Associates, Inc. The primary technical work on this report was the responsibility of A. T. Kearney, Inc. This document supercedes all deliverable working papers. This report is the sole official deliverable available for use under this Project Element.

National Waterways Study

FINAL REPORT

EVALUATION OF THE PRESENT NAVIGATION SYSTEM

UNITED STATES CORPS OF ENGINEERS
EVALUATION OF THE PRESENT NAVIGATION SYSTEM

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I - INTRODUCTION

Evaluation of the Present Waterway System is one of 11 reports prepared by Kearney: Management Consultants, Inc. in association with Data Resources, Inc. and Louis Berger and Associates for the National Waterways Study (NWS). The National Waterways Study is sponsored by the Institute for Water Resources, United States Corps of Engineers.

The rest of this section is divided into:

- Study Objectives and Scope.
- Study Organization.
- Purpose and Organization of this Report.
- Public Participation.
- Organization of this Report.

STUDY OBJECTIVES AND SCOPE

(a) NWS Objectives

The objectives of the NWS are to:

> *IDENTIFY* AND ANALYZE ALTERNATIVE STRATEGIES FOR PROVIDING A NAVIGATION SYSTEM TO SERVE THE NATION'S CURRENT AND PROJECTED TRANSPORTATION NEEDS.

For purposes of this study, strategies are defined as alternative sets of policy and top management directives for taking actions to meet water transportation needs. Transportation needs are defined as the changes in the navigation system that would be required to handle current and projected waterborne commodity flows safely and at a marine line-haul cost consistent with the historical cost relationship among transportation modes. The use of the word "needs" is not intended to suggest changes in the navigation system which must be undertaken at any cost.

In requesting the Corps to undertake this study, the Congress is seeking to obtain information on the broad options available to it for meeting the needs of water transportation users through the year 2000. In contrast to the normal congressional review of individual projects, Congress, in requesting this study, is seeking information about the nation's overall navigation system and strategies to improve it.

(b) NWS Scope

In order to understand the scope of the NWS, it is necessary to state what the NWS is not. NWS is not a national transportation study. Strategies have neither been identified nor evaluated with regard to shortfalls in rail, truck, or pipeline capacity, even though, for example, rail transportation bottlenecks, if unalleviated, can be expected to affect greatly the growth and development of individual coastal ports.

NWS is not a water resource study. The study was designed from the beginning to formulate strategies for meeting water transportation needs. Other uses of water that compete with or complement water transportation use have been discussed in a NWS report entitled Navigation Relationship to Other Water Uses and the principal findings of this study have been incorporated into the methodology of this report.

Finally, NWS is neither a detailed plan for Congress and the Corps to implement nor a project feasibility study. Instead, the NWS is meant to identify and evaluate the basic options available to Congress, the Corps, and other maritime agencies for meeting current and projected water transportation needs.

(c) System Baseline

For purposes of this study, the present waterways system is defined as the currently used waterways system as of December 1978. However, the following commercial

navigation projects that are funded for construction or under construction have been included in the present waterways system: the completion of the Tennessee-Tombigbee Waterway; the completion of the Red River; the completion of the 12' channel deepening project on the Lower Mississippi between Cairo and Baton Rouge; the 1200' by 110' lock replacement project at Lock and Dam 26 on the Mississippi at Alton, Illinois; the Vermilion lock replacement project on the Gulf Intracoastal Waterway West; two lock replacement projects on the Ouachita River; and a second lock chamber at Pickwick Lock and Dam on the Tennessee.

It should be noted that the "present waterways system" examined in NWS is primarily the collection of active federal navigation projects presently in existence. This is not the same thing as the "waters of the United States" or the "navigable waterways" of the United States defined for regulatory purposes. For NWS purposes, the present system includes federal waterways which either carry traffic or incur costs charged to navigation and are recorded in the NWS inventory. Also included in the present system for NWS purposes are some non-federal facilities, namely the New York State Barge Canal system and the Canadian portion of the St. Lawrence Seaway, including the Welland Canal.

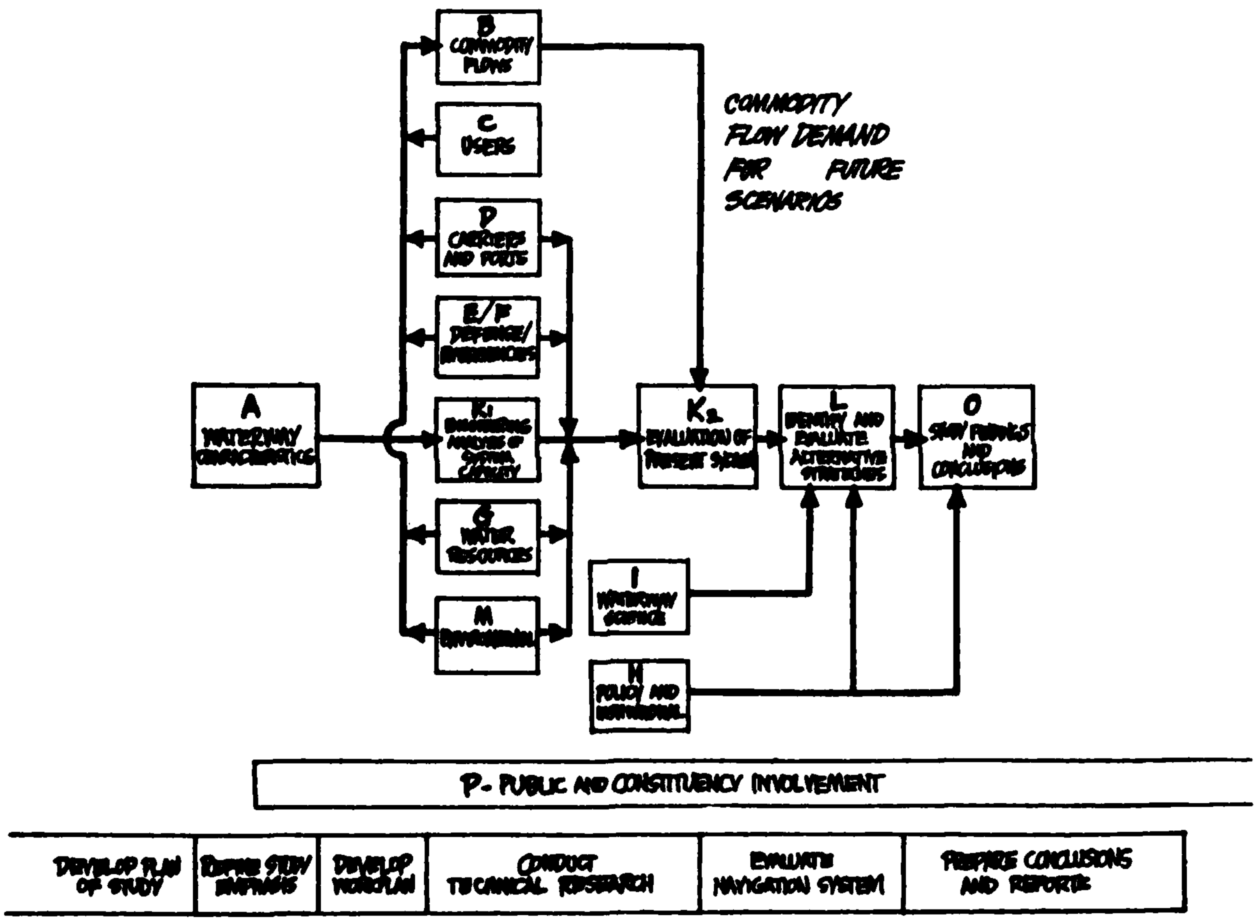
For reporting purposes, the present waterways system has been divided into 22 geographical areas. These 22 areas have, in turn, been divided into 61 segments for analysis purposes. Exhibit I-1 presents a listing of these regions and segments. Waterborne commodity flows are presented later in this report for reporting purposes in 14 commodity groups. These 14 groups are, in turn, aggregations of 48 analytical commodities. Exhibit I-2 presents a listing of these commodities.

STUDY ORGANIZATION

In order to meet the NWS objectives, a series of technical analyses and integration steps had to be completed. Figure I-A depicts the NWS work plan finalized in June of 1979 and the manner in which the pieces of the study fit together.

Figure I-A

National Waterways Study Elements



As can be seen by this figure, the NWS has been divided into 14 "elements" involving efforts by the contractor, IWR/NWS team and the Corps field organization. Public involvement has been sought throughout the NWS. Element A served primarily as input to Element K1. Elements C, D, E/F, G, and M all provided input at varying levels to the commodity flow projection process of Element B. In addition, Elements D, E/F, K1, G, and M provided input to Element K2, the evaluation of the present waterways system.

PURPOSE OF THIS REPORT

Element K2, the portion of NWS which is the subject of this report, is a key "integration" task. Its purpose is to evaluate the capability of the present waterway system to handle current and projected waterborne commodity flows.

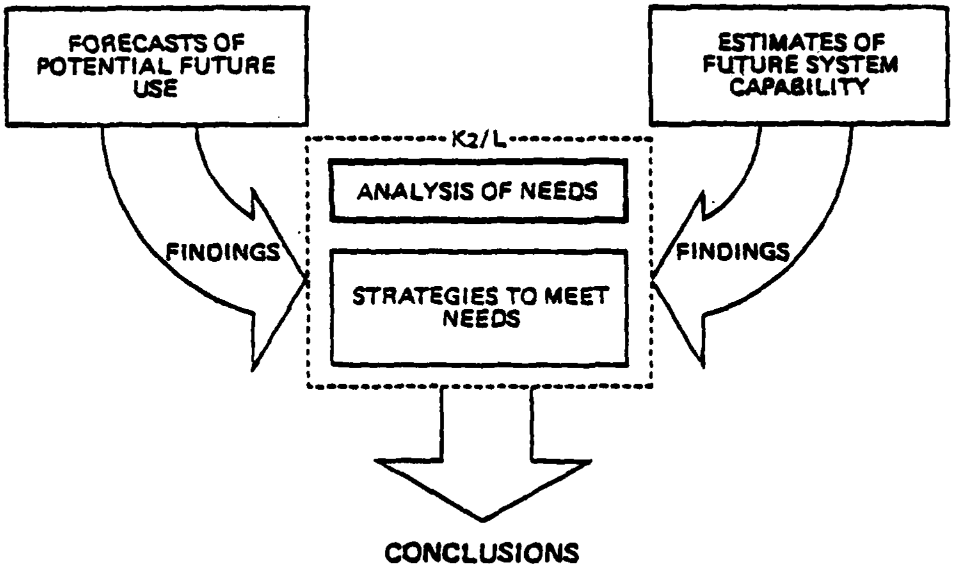
(a) Present System Evaluation

Evaluation of the present waterway system is based on four scenarios of future waterborne commodity flow projections and several sensitivity analyses. For purposes of the NWS, scenarios are collections of assumptions about related factors in the economy, society, or government that, taken together, affect the future use of the waterways for transportation. Sensitivity analyses are undertaken to determine whether different study conclusions are reached if changes in key assumptions are made.

The integration processes of Elements K2 and L are depicted in Figure I-B. As can be seen by this figure, the prior technical work of Elements A, B, C, D, E/F, K1, G, and M is represented by forecasts of potential future use of the waterways and estimates of waterway capability. The K2 effort involves determining water transportation needs by comparing forecasts of present and projected water transportation use with estimates of the capability of the waterway system.

Figure I-B

National Waterways Study
Summary of Project Flow



(b) Objective of This Report

Thus, the objective of this document is to determine water transportation needs for the present navigation system, which includes inland, Great Lakes, and coastal waterways. The needs identified are not definitive in the same sense that project level studies are definitive. Disaggregation of national traffic forecasts cannot reflect all local commodity movements. However, such an approach can be used to generalize about the shortcomings of the present waterway system and to identify and evaluate broad strategies for action.

Once needs have been determined in Element K2, action strategies to meet these needs are identified and evaluated in Element L.

This report presents findings and conclusions regarding the ability of the present waterway system to handle current and projected waterborne commodity flows. No recommendations are made. Nor are strategies identified or evaluated.

PUBLIC PARTICIPATION

Public participation was an integral part of the process of formulating the Element K2 findings. A public forum was held in Washington, D.C. on September 4, 1980. The purposes of this forum were to present for public review the preliminary conclusions from prior technical work as well as the methodology and preliminary findings regarding the evaluation of the present waterway system. As a result of this meeting, additional data on new commodity flows and capacity at specific locks were obtained.

Public briefings were also held on November 13, 18, and 19 in Washington, D.C., St. Louis, and Portland, Oregon. The purposes of these briefings were to present for public review the preliminary findings of the evaluation of both the present waterway system and the four NWS strategies for action. Public comments were explicitly solicited regarding the type of sensitivity analyses to be conducted by the contractor before completing this report.

ORGANIZATION OF THIS REPORT

The rest of this report is divided into the following five sections and six appendices:

1. Section II presents the analytical framework upon which the evaluations of the present system for meeting needs is based.

2. Section III describes the purpose and development of the four NWS scenarios and three sensitivity forecasts.

3. Section IV discusses the factors affecting the transportation capability (capacity, safety, and line-haul costs) of the present navigation system.

4. Section V presents the findings of the evaluation of the present navigation system. The locks constraining future traffic are identified. The ton-mile costs of water transportation, potential safety problems, and the results of selected sensitivity analyses are all also presented in this section.

5. Section VI presents the conclusions from the evaluation of the present navigation system.

6. Appendix A (published under separate cover) presents the forecasts for four scenarios at the reporting region level. For reporting purposes, the national waterways have been divided into 22 separate regions.

7. Appendix B is a discussion of the relationship between the lock capacity analysis performed in Element K1 and the subsequent analysis performed in Element K2/L.

8. Appendix C is a discussion of the methodology for calculating lock capacity and a presentation of the base-year data for all commercially important locks.

9. Appendix D is a discussion of the methodology for calculating line-haul costs of domestic marine operations and a presentation of the data used to compute line-haul costs.

10. Appendix E contains sensitivity analyses of capacity estimates for selected locks.

11. Appendix F contains an analysis of obsolete locks.

Throughout this report references are made to other NWS Elements and reports. The purpose of this report is to draw on prior work as well as to present current analysis. This report does not duplicate prior efforts

nor deal with various issues in the same depth of detail as prior reports. Readers who desire more information on some of these issues should refer to the other NWS Element Reports.

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
1	Upper Mississippi River	Minneapolis, MN to Mouth of Illinois River	1	Upper Mississippi
2	Lower Upper Mississippi River	Mouth of Illinois River to mouth of Ohio River at Cairo, IL.	2	Lower Upper Mississippi River (Illinois River to Missouri River)
			3	Middle Mississippi River (Missouri River to Ohio River including Kaskaskia River)
3	Lower Mississippi River: Cairo to Baton Rouge	Mouth of Ohio Rivr (Cairo, IL) to Baton Rouge, LA.	4	Lower Middle Mississippi River (Ohio River to White River)
			5	Upper Lower Mississippi River (White River to Old River)
			6	Lower Mississippi River - Old River to Baton Rouge
4	Lower Mississippi River: Baton Rouge to Gulf	Baton Rouge, LA (including port) to Mouth of Passes and other channels and rivers.	7	Mississippi River - Baton Rouge to New Orleans
			8	Mississippi River - New Orleans to Gulf
			25	Ouachita - Black and Red Rivers
			26	Old and Atchafalaya Rivers,
			27	Baton Rouge to Morgan City, La. Bypass
5	Illinois Waterway	Chicago, IL (Guard Lock and T.J. O'Brien Lock) to Mouth of Illinois River	9	Illinois Waterway
6	Missouri River	Sioux City, IA to Mouth at Mississippi River	10	Missouri River

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
7	Ohio River	Heads of navigation to Mouth	11	Upper Ohio river (Confluence of Monongahela and Allegheny at Pittsburgh, PA to Kanawha River)
			12	Middle Ohio River (Kanawha River to Kentucky River)
			13	Lower Ohio River - Three (Kentucky River to Green River)
			14	Lower Ohio River - Two (Green River to Tennessee River)
			15	Lower Ohio River - One (Tennessee River to Mouth)
			16	Monongahela River
			17	Allegheny River
			18	Kanawha River
			19	Kentucky River
			20	Green River and Barren River
			21	Cumberland River
8	Tennessee River	Head of navigation ab ve Knoxville, TN to Mout	22	Upper Tennessee River and Clinch River (Head of navigation to junction with Tennessee-Tombigbee Waterway)
			23	Lower Tennessee River (from junction with Tennessee-Tombigbee Waterway to Ohio River)
9	Arkansas River	Catoosa, OK (near Tulsa, OK) to Mouth	24	Arkansas River (including Verdigris, White, and Black Rivers)
10	Gulf Coast West	New Orleans to Brownsville, TX	28	GIWW West One (from New Orleans, LA to Calcasieu River)

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
10	Gulf Coast West	New Orleans, LA to Brownsville, TX	29	GIWW West Two (Calcasieu River to Corpus Christi, TX)
			30	GIWW West Three (Corpus Christi to Brownsville)
			34	Houston Ship Channel
11	Gulf Coast East	New Orleans to Key West, FL	31	GIWW East One (New Orleans to Mobile Bay, including Mississippi River Gulf Outlet and Pearl River)
			32	GIWW East Two (Mobile Bay to St. Marks, FL)
			33	Florida Gulf Coast (St. Marks, FL to Key West, FL)
			38	Apalachicola, Chattahoochee, Flint Rivers
12	Mobile River and Tributaries	Heads of navigation to Mouth	35	Black Warrior - Mobile Harbor (Black Warrior River - Head of navigation to Mouth, Tombigbee River - Mouth of Black Warrior River to confluence with Alabama River, Mobile River to Mobile Bay, Mobile Harbor)
			36	Alabama-Coosa Rivers
			37	Tennessee-Tombigbee Waterway
13	South Atlantic Coast	Key West, FL to North Carolina/Virginia Border	39	Florida/Georgia Coast
			40	Carolinas Coast
14	Middle Atlantic Coast	North Carolina/Virginia Border to New York/Connecticut Border	41	Chesapeake and Delaware Bays
			42	New Jersey/New York Coasts

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
15	North Atlantic Coast	Hudson River from Waterford, NY to Mouth; New York/Connecticut Border to Canada Border	44	North Atlantic Coast
16	Great Lakes/St. Lawrence Seaway/New York State Waterways		43	New York State Waterways
			45	Lake Ontario and St. Lawrence Seaway
			46	Lake Erie
			47	Lake Huron
			48	Lake Michigan
			49	Lake Superior
17	Washington/Oregon Coast	Puget Sound to California-Oregon Border	50	Puget Sound
			53	Oregon/Washington Coast
18	Columbia-Snake Waterway/ Willamette River	Lewiston, ID to Mouth	51	Upper Columbia-Snake Waterway (Lewiston, ID to Bonneville Lock and Dam)
			52	Lower Columbia-Snake Waterway/ Willamette River (from Bonneville Lock to Mouth)
19	California Coast	California-Oregon Border to Mexico Border	54	Northern California (Oregon-California Border to San Francisco Bay)
			55	San Francisco Bay Area, Sacramento River, and San Joaquin River
			56	Central/South California (from San Francisco Bay to Mexico Border)

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
20	Alaska		57	Southeast Alaska (panhandle)
			58	South Central Alaska Coast
			59	West and North Coasts of Alaska (including Aleutians)
21	Hawaii and Pacific Territories		60	Hawaii and Pacific Territories
22	Caribbean, including Puerto Rico and Virgin Islands		61	Caribbean, including Puerto Rico and Virgin Islands
			62	Rest of World (not included as part of a Reporting Region)

NWS REPORTING AND ANALYSIS COMMODITY GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
I.	Farm Products			
		1	Corn	0103
		2	Wheat	0107
		3	Soybeans	0111
		4	Other Farm Products	0101, 0102, 0104, 0105, 0106, 0112, 0119, 0121, 0122, 0129, 0131, 0132, 0133, 0134, 0141, 0151, 0161, 0191
II.	Metallic Ores			
		5	Iron Ore and Concentrates	1011
		6	Other Ores (including Bauxite)	1021, 1051, 1061, 1091
III.	Coal			
		7	Coal and Lignite	1121
IV.	Crude Petroleum			
		8	Crude Petroleum	1311

NWS REPORTING AND ANALYSIS COMMODITY GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
V.	Nonmetallic Minerals			
		9	Sand, Gravel, and Crushed Rock	1442
		10	Limestone	1411
		11	Phosphate Rock and Other Fertilizers	1471, 1479
		12	Sulphur	1492, 1493
		13	Other Nonmetallic Minerals	1412, 1451, 1491, 1494, 1499
VI.	Food and Kindred Products			
		14	Vegetable Oils	2091
		15	Grain Mill Products	2041, 2042, 2049
		16	Other Food Products	2011, 2012, 2014, 2015, 2021, 2022, 2031, 2034, 2039, 2061, 2062, 2081, 2092, 2094, 2095, 2099
VII.	Lumber and Wood Products			
		17	Logs (including Pulpwood)	2411, 2415
		18	Rafted Logs	2412
		19	Lumber and Plywood	2421, 2431
		20	Other Lumber and Wood Products	2413, 2414, 2416, 2491

NWS REPORTING AND ANALYSIS COMMODITY GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
VIII.	Pulp, Paper and Allied Products			
		21	Pulp	2611
		22	Other Pulp and Paper Products	2621, 2631, 2691
IX.	Chemicals			
		23	Sodium Hydroxide	2810
		24	Crude Tar, Oil and Gas Products	2811
		25	Alcohols	2813
		26	Benzene and Toluene	2817
		27	Sulphuric Acid	2818
		28	Other Chemicals	2816, 2819, 2812, 2821, 2822, 2823, 2831, 2841, 2851, 2861, 2876, 2891,
		29	Nitrogenous Chemical Fertilizers	2871
		30	Potassic Chemical Fertilizers	2872
		31	Phosphatic Chemical Fertilizers	2873
		32	Other Fertilizer Products	2879, 2875
X.	Petroleum and Coal Products			
		33	Gasoline	2911
		34	Jet Fuel and Kerosene	2912, 2913

NWS REPORTING AND ANALYSIS COMMODITY GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
X. (Cont'd)		35	Distillate	2914
		36	Residual	2915
		37	Other Petroleum and Coal Products, nec	2916, 2917, 2918, 2920, 2921, 2951, 2991
XI.	Stone, Clay, Glass, and Concrete Products			
		38	Cement	3241
		39	Other Stone, Clay, Glass Products	3211, 3251, 3271, 3281, 3291
XII.	Primary Metals Products			
		40	Coke	3313
		41	Iron and Steel Primary Forms	3314
		42	Steel Mill Products (shapes, plates, pipe and tube)	3315, 3316, 3317
		43	Primary Metals	3311, 3312, 3318, 3319, 3321, 3322, 3323, 3324
XIII.	Waste and Scrap			
		44	Metal Scrap	4011, 4012
		45	Other Scrap	4022, 4024, 4029

NWS REPORTING AND ANALYSIS COMMODITY GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
XIV.	Other Commodities			
		46	Marine Shells	0931
		47	Miscellaneous	
			Forest Products	0841, 0861
			Fish	0911, 0912, 0913
			Ordnance	0911
			Tobacco	2111
			Textiles	2211, 2212, 2311
			Furniture	2511
			Printed Matter	2711
			Rubber Products	3011
			Leather	3111
			Fabricated Metal	3411
			Machinery	3511, 3611
			Transportation Equipment	3711, 3721, 3731, 3791
			Instruments, Optical Goods, etc.	3811
			Miscellaneous Manufacturers	3911
			Water	4111
			Commodity, nec	4112
			LCL Freight	4113
			Department of Defense Cargo	9999
		48	Water Improvement Materials	4118

II - ANALYTICAL FRAMEWORK

This section is divided into two parts:

- Sources for the Integration Framework.
- Description of the Integration Framework.

The first presents the sources upon which the integration framework for evaluating the present waterway system is based. The second explains the principal components of the final integration framework developed for this study.

SOURCES FOR THE INTEGRATION FRAMEWORK

As discussed in the Introduction, the purpose of Element K2 is to integrate the technical findings and conclusions of prior NWS work in order to evaluate the capability of the present waterway system to meet present and projected water transportation use. A number of sources have been used to develop the integration framework presented in this document. The initial development of the integration framework began with the Study Workplan.

Figure II-A presents the original version of the integration framework as developed in the Study Workplan. This original version provides the key components of the integration approach and is presented here to provide documentation of how the integration process itself evolved.

As can be seen by Figure II-A, it was originally envisioned that there would be up to 10 scenarios -- corresponding to the 10 numbered columns at the top of the matrix. Each scenario was to be defined by specifying assumptions about "uncontrollable" factors. These are factors that, on the one hand, can be expected to influence the use of the waterways for transportation and, on the other hand, are not within the control of water transportation planning and management. Examples of these factors include macro-economic conditions and industry conditions.

Figure II-A

STUDY WORKPLAN INTEGRATION FRAMEWORK

DEFINITION OF NWS SCENARIOS	1	2	3	4	5	6	7	8	9	10
UNCONTROLLABLE FACTORS: Conditions which affect the navigation system, but which are not part of controllable factors considered in developing the alternative strategies. FACTOR CATEGORIES include, but are not limited to: MACROECONOMIC CONDITIONS TRANSPORTATION MODAL NETWORK CONFIGURATION FUTURE DEVELOPMENT OF NON-WATER MODES TRANSPORTATION POLICY (Applicable to all modes as opposed to waterway policy). ENVIRONMENTAL POLICY ENERGY POLICY WATER RESOURCE POLICY INDUSTRY CONDITIONS (Specific factors for development of key industries which represent a high portion of current waterway use. OTHER GOVERNMENTAL POLICIES										
FORECAST OF FUTURE TRANSPORTATION USE OF THE WATERWAYS FOR EACH SCENARIO TO ESTIMATE FUTURE NEEDS (Unconstrained by capacity or other controllable factors.										
ESTIMATE ABILITY OF THE WATERWAY SYSTEM TO MEET PROJECTED NEEDS (Present system and present system incorporating improved technology.										
DEFINE "SHORTFALL" IN MEETING NEEDS UNDER EACH SCENARIO										
FORMULATE ALTERNATIVE STRATEGIES WHICH WILL BETTER MEET PROJECTED NEEDS. (These potentially include programs to manage demand, increase capacity, and combinations of these types of programs.) EACH STRATEGY WILL BE DEFINED IN TERMS OF (Factors within the scope of the study and potentially controllable in terms of the recommendations developed): LAW AND AUTHORITIES INSTITUTIONAL AND REGULATORY FACTORS MANAGEMENT AND POLICY CAPITAL INVESTMENT (construction) PROGRAMMING OPERATIONAL MANAGEMENT DECISIONS MAINTENANCE MANAGEMENT DECISIONS										
EVALUATION MEASURES APPLIED TO ASSESS ADVANTAGES AND DISADVANTAGES OF EACH STRATEGY UNDER THE CONDITIONS REPRESENTED BY EACH SCENARIO. (Application can be national, regional, or both as illustrated by N, R) EVALUATION MEASURES WILL BE GROUPED ACCORDING TO THE CATEGORIES PRESENTED IN PRINCIPLES AND STANDARDS. POSSIBLE EVALUATION MEASURES INCLUDE, BUT WILL NOT BE LIMITED TO: TONS TRANSPORTED BY COMMODITY GROUP MAXIMUM THROUGHPUT AVERAGE TOW DELAY TIME MAXIMUM TOW SIZE ACCOMODATED TOTAL TON-MILES PRODUCED BY COMMODITY GROUP AVERAGE DAYS IN SERVICE AVERAGE TOW TRAVEL TIME TRANSPORT COST PER TON-MILE INTER-RELATIONSHIP EFFECTS ON OTHER GOALS SUCH AS IRRIGATION AREA SERVED, HYDROPOWER OUTPUT, FLOOD CONTROL CAPABILITY, RECREATION SERVICE, WATER SUPPLY SERVICE, LOW FLOW, AQUATIC HABITAT, MEETING OF DEFENSE AND EMERGENCY NEEDS, MEETING OF NEEDS FOR AQUATIC AND TERRESTIAL HABITAT, EFFECTS ON AIR, WATER, AND OTHER ENVIRONMENTAL CONDITIONS, AND IMPACTS ON REGIONAL INCOME AND EMPLOYMENT.	N R	N	N	N	N	N	R	N	R	N

A forecast of projected use was to be developed for each scenario. These forecasts were then to be compared to estimates of the ability of the present waterway system to handle traffic. A list of "shortfalls" in capacity would be defined by these comparisons.

The next phase (reported in Element L - Evaluation of Alternative Future Strategies for Action) of the analysis was to be the formulation of alternative strategies for action. These strategies were to be defined by "controllable" factors, i.e., factors or actions within the scope of the study and under the control of water transportation decision-makers.

The final phase of the Element L (Evaluation of Alternative Future Strategies for Action) analysis was to be the evaluation of alternative strategies for action. The advantages and disadvantages of each strategy were to be assessed by calculating and presenting measures of transportation and non-transportation impacts for each scenario-strategy combination.

Since the completion of the Study Workplan, a considerable amount of work has been done to refine the original version of the integration framework. Interviews were conducted with Corps personnel in field offices and Corps top management at headquarters. Public briefings were conducted in December 1979 and January 1980 to review the analytical framework. Interim task reports have been written by the K2/L contractor element team in the spring and summer of 1980 and were reviewed by the Corps.

Finally, the NWS reports entitled Traffic Forecasting Methodology (the Element B Report), Commercial Water Transportation Users (the Element C Report), Overview of the Transportation Industry (the Element D Report), Review of National Defense, Emergency, and Safety Issues Affecting the Waterway (the Element E/F Report), Analysis of Navigation Relationships to Other Water Uses (the Element G Report), Engineering Analysis of Waterway Systems (the Element K1 Report) and Analysis of the Environmental Aspects of Waterways Navigation (the Element M Report) were reviewed and appropriate findings were incorporated in the development of the final integration

plan. These reports summarize the technical findings and conclusions of prior NWS work.

Some of these findings were not anticipated in the original draft of the integration plan. For example, other uses of water, such as hydro-power, irrigation, recreational boating, and residential and industrial consumption were determined to pose no significant (i.e., national) conflict to the use of the waterways for commercial transportation (see the NWS report entitled Navigation Relationship to Other Water Uses). Although conflicts between commercial navigation and other uses occur on such rivers as the Alabama, Apalachicola, Chattahoochee, and Flint and may occur during the next 20 years on the Missouri River, these segments account for only a small fraction of total national traffic. Since varying assumptions about the use of water for other purposes do not result in differing estimates of water transportation capability, no assumptions about these uses were incorporated in any of the final NWS scenarios.

Another example of the technical findings of prior work incorporated in the final integration framework is the conclusion from Element K1 (Engineering Analysis of Waterways Systems) work that the physical capacity of locks is the principal reason for any shortfall in the present system's capability to accommodate projected use. In contrast to channels with locks, the physical capacity of open channels or such channels constricted by one or more other hazards to navigation, (e.g., as the Upper Mississippi River that are swing bridges with horizontal clearances of 110 to 160 feet), was found to be in excess of any projected traffic levels. Since locks are the principal cause of any shortfall in capacity, the comparison of projected use with system capability was made at the lock level rather than the analytical segment level as originally envisioned.

This continued refinement of the integration process culminated in a Final Integration Plan presented to the Corps of Engineers in July, 1980. While many adjustments to that plan have occurred, that plan was executed and provided the final basis and scope of the integration effort. This report and the L Report (Evaluation of Alternative

Future Strategies for Action) document the execution process and analytical results. The INTEGRATION FRAMEWORK described under the next subject heading of this chapter is drawn from the final plan.

DESCRIPTION OF THE FINAL INTEGRATION FRAMEWORK

The final integration framework is depicted in Figure II-B. The five columns in Figure II-B correspond to the four NWS scenarios plus selected sensitivity analysis. The entire integration process is performed for each scenario. This process is represented by the seven steps along the left side of Figure II-B. Each of these steps is discussed below.

Each scenario represents an alternative view of the future. The decision-maker's universe can be divided between past versus future, acts versus events, and certainty versus uncertainty. Decision-making deals with affecting factors within control (acts in the future), but it requires an understanding of factors outside control (events of the future). Scenarios represent the events in the future, for the purposes of this study, which are outside the control of the strategies being formulated. A scenario is, thus, a collection of assumptions about related factors in the economy, society, or government that, taken together, will affect the future needs for water transportation.

As part of the process of defining a scenario, it is necessary to specify the assumptions about uncontrollable events. It is these assumptions that are altered from one scenario to another. Technical estimates are the result of analytical work performed to estimate the impact of scenario assumptions on traffic forecasts.

Originally, it was anticipated that up to 10 scenarios would be developed. A scenario entitled "low flow" was originally one of the ten NWS scenarios. It was to

Figure II-B

NATIONAL WATERWAYS STUDY
FINAL INTEGRATION FRAMEWORK

	SCENARIOS				
	BASELINE	HIGH USE	LOW USE	BAD ENERGY	SENSITIVITY ANALYSES
	1	2	3	4	5
ASSUMPTIONS AND TECHNICAL ESTIMATES ABOUT UNCONTROLLABLE EVENTS					
WATERBORNE COMMODITY FLOW PROJECTIONS					
TRANSPORTATION CAPABILITY OF PRESENT WATERWAYS SYSTEM					
WATER TRANSPORTATION NEEDS					
APPLICATION OF STRATEGIES					
DESCRIPTION OF STRATEGY OUTCOMES					
EVALUATION OF STRATEGY EFFECTS					
SENSITIVITY ANALYSES					

represent hydrological conditions that effectively reduce the capability of the waterways system for a period of one to five years. On the basis of prior technical work performed by Elements G (Analysis of Navigation Relationships to Other Water Uses) and K1 (Engineering Analysis of Waterways Systems), it was determined that only one relatively important waterway segment, namely the Lower Upper Mississippi River, was a logical candidate for the low flow scenario. It was also determined that it was not possible to state with precision what the relationship would be between specific hydrological conditions and channel depth on the Lower Upper Mississippi River. A possibility was to define a set of conditions on the Lower Upper Mississippi that was comparable to the 1976 problem in this region. However, the set of conditions would have to be stated somewhat arbitrarily (namely that channel depth would be reduced) rather than rigorously (namely that the presence of certain hydrological conditions with a probability of occurrence would cause a reduction in channel depth and width). As a result, the idea of a low flow scenario was dropped altogether, because it was not possible to capture the more refined condition which would produce more meaningful analysis.

Three of the original ten scenarios described in the NWS workplan, namely "defense", "least favorable to waterways", and "most favorable to waterways", were subsequently adopted as sensitivity analyses. A separate analysis of the evaluation of the present system under defence conditions is presented in Section V of this document. The most favorable and least favorable scenarios represent alternative assumptions about national environmental policy. The sensitivity of waterway construction, maintenance and operation costs to changes in environmental policy is discussed in the Element L Report, entitled Evaluation of Alternative Future Strategies for Action.

Two other scenarios also mentioned in the NWS workplan, namely "more government" and "less government", were dropped only after it was determined that the forecasts corresponding to each of these scenarios differed little from those of the low use and baseline scenarios, respectively.

The waterborne commodity flow projections are estimates of commodity flows that can be expected to move by water if there is adequate waterway capability to handle this traffic. In other words, these are projections of water transportation use unconstrained with regard to considerations of waterway capability.

The transportation capability of the present waterways system is defined as the ability of the system to accommodate projected flows safely and at a marine line-haul cost consistent with the historical cost relationship among transportation modes. Its assessment is based in part on the prior technical work performed in Elements K1, D, E/F, G, and M. This prior technical work involved identifying potential constraints to the growth of traffic at the present time and gathering the necessary data to estimate the impact of potential constraints under different future traffic projections.

Water transportation needs are the changes in the navigation system that would be required to handle current and projected waterborne commodity flows safely and at a marine line-haul cost consistent with the historical cost relationship among transportation modes. Based upon the concepts of water transportation capability discussed in Section IV of this report, three types of analyses are performed to determine needs. First, physical shortfalls in lock capacity over time are identified throughout the present waterway system under four alternative scenarios and selected sensitivity analyses. Second, ton-mile costs are computed to estimate the private costs of marine line-haul operations. Third, an analysis of safety issues and problems is undertaken.

Having determined transportation needs, alternative strategies for action are formulated. Congress, the Corps of Engineers, and other government agencies have a number of options to meet future water transportation needs. Strategies are alternative sets of policy and top management directives, which control the development of specific plans and programs for action. As discussed

earlier,[1] the Element L report (Evaluation of Alternative Future Strategies for Action) identifies and evaluates the NWS strategies.

The application of strategies is the process of determining what actions will be taken at what time and cost under different combinations of scenarios and strategies. Actions are defined as discreet changes in Operations and Maintenance Activities, or discreet structural and non-structural changes in system infrastructure or operating policies or procedures. The process utilizes a set of decision rules under each strategy for determining if and when appropriate actions under each strategy will be implemented to address water transportation needs.

The description of strategy outcomes lists the program results from implementing a strategy for a particular scenario. Lists of the actions taken in 5 year periods are prepared for each scenario-strategy combination. These actions include channel maintenance, lock operations, rehabilitation of waterway structures, lock expansion, safety, and enhancement of water transportation by channel and port deepening.

Evaluation of strategy effects is the assessment of the relative goodness or badness of strategies with regard to issues of national concern. Thirteen NWS evaluation measures have been computed for scenario-strategy combinations and these are:

1. Traffic handled as a percentage of projected usage (waterway traffic actually handled by the present waterways system after taking into account lock constraints divided by the projected use of the waterways).

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[1] Four NWS strategies have been identified and evaluated. These are titled: continuation of present policies; reprioritization of a fixed budget; full funding of present system; and enhance navigation system capability. These are fully defined and described in the Element L report.

2. Traffic in tons not accommodated by the present system due to lock capacity constraints.

3. Traffic handled as a percentage of total production plus imports of key waterway industries (waterway traffic actually handled for the agriculture, steel, coal, and petroleum industries divided by domestic production of grain and grain products, domestic consumption of iron ore, coke, and steel products, domestic production of coal, and domestic consumption of petroleum and petroleum products, respectively).

4. Private marine line-haul costs (estimated private ton-mile costs of the line-haul operations of tows on the inland segments and vessels on the Great Lakes taking into account: tow size, lading, speed, lock delays, percent of time that vessels or tows are loaded, escalation of the real price of fuel, imposition of taxes on the sale of marine fuel for inland navigation by Public Law 95-502, and improvements in the average fuel consumption of towboats and vessels from 1977 to 2003).

5. Public expenditures (public expenditures for the operations, maintenance, rehabilitation, and improvement of the present waterways system under alternative strategies for action in 1977 dollars).

6. Fuel tax revenues (annual fuel tax revenues collected under Public Law 95-502 in 1977 dollars).

7. Average lock utilization (waterway traffic at locks in tons divided by the practical capacity of these locks in tons. Practical capacity is defined as that level of throughput corresponding to 90% utilization of the theoretical capacity of a lock chamber after taking into account lock chamber dimensions, chamber availability, cycle time, average chamber utilization as determined by traffic mix, percentage of loaded barges or vessels, average ladings as determined by traffic mix, and lock operating procedures)[2].

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2 Ninety percent of the theoretical capacity of a lock generally corresponds to an average delay of three to five hours per tow or vessel.

8. Safety indicators:

(a) Increase in projected usage[3] (increase in tons of projected usage over 1977 traffic levels).

(b) Share of hazardous commodities[3] (projected use of hazardous commodities divided by total projected use).

(c) Average tow size as a percent of maximum accommodated tow size[3] (weighted average tow size for inland waterways divided by the maximum tow size that can be safely accommodated.

(d) Average lock delay in hours per tow or vessel.[3]

In addition, the generic impacts of actions on the environment are discussed.

Values of each of these measures have been calculated for scenario-strategy combinations as part of the Element L analysis and will be presented in the Element L Report (Evaluation of Alternative Future Strategies for Action). The values of some of these same measures are discussed as part of the evaluation of the present system in Section V of this report.

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3 These measures are used to assess the change in safety conditions over time for commercial navigation.

The final step of the integration framework is the sensitivity analysis, which the public briefings in September and November 1980 played key roles in shaping. The purpose of the sensitivity analysis is to test the sensitivity of Element K2 and L findings to changes in key assumptions. Four types of analyses were performed. First, changes were made to projected use. Three additional forecasts were developed including: high coal exports; a defense forecast; and upward adjustments to traffic on the Ohio, Monongahela, Arkansas, Columbia-Snake Waterway, and Inner Harbor Navigation Canal. Second, the effects of incorporating site specific minor structural actions on the calculation of capacity for a few unique locks was examined. Third, the volume of dredging was reduced from the base year amounts for the Arkansas and Missouri Rivers to reflect the "maturing" of these waterways. Fourth, the sensitivity of the public costs of waterways operations and improvements to a tightening and a relaxation of present environmental policies was estimated. The first and second analyses are presented in Section V of the K2 report (Evaluation of the Present Navigation System). The implications of the first and the third and fourth analyses for the evaluation of strategies are presented in the L report (Evaluation of Alternative Future Strategies for Action).

The above discussion provides an overview of the integration framework being utilized for the NWS. The integration framework provides a systematic and comprehensive process for drawing together the findings and conclusions of the study and focusing them on the key study objectives. At the same time, the approach is not mechanistic nor does it determine any "best" solutions. It is purposely designed to examine and illustrate the advantages and disadvantages of alternative strategies for the policy makers' assessment.

III - SCENARIOS AND FORECASTS

INTRODUCTION

This section describes the four NWS scenarios and the corresponding waterborne commodity flow projections through the year 2003. For the purpose of this study, the NWS scenarios are collections of assumptions about related factors in the economy, society, and government that, taken together, will impact the future needs for waterborne transportation in the United States. Waterborne commodity flow projections are forecasts of the use of the waterways for transportation in tons for foreign traffic and in both tons and ton-miles for domestic traffic. These projections are considered to be unconstrained with regard to considerations of lock or port capacity, but constrained with regard to a series of macroeconomic, industry, energy, and port share assumptions. These are not projections of waterborne traffic. Instead, they represent projections of waterway transportation use by major United States industries that have traditionally used water movements in their logistics systems. In addition, new movements that may occur in the future, such as those arising from the development of synthetic fuels, are also included in the projections.

BACKGROUND

Four alternative scenarios were developed to forecast United States waterborne movements for fourteen commodity groups (see Exhibits I-1 and I-2 for a listing of these regions and commodities) and twenty-two reporting regions.

The rest of this section is divided into three sub-sections:

- Scenario Development and Descriptions.
- Total Traffic Forecasts by Scenario.
- Scenario Differences by Commodity.

The description of the four NWS scenarios lists the key differences in assumptions from one scenario to another. The subsection on total traffic forecasts draws some national conclusions about these projections. The final subsection presents the key differences across the four scenarios for the five commodity groups (coal, petroleum, chemicals, grain, and iron and steel) responsible for the major differences in waterborne commodity flows by scenario.

SCENARIO DEVELOPMENT AND DESCRIPTION

(a) Scenario Purposes

Scenarios have three purposes. One of the purposes of scenarios is to summarize the type and magnitude of events that are likely to influence the future use of the waterways. Factors that cannot be expected to affect water transportation use are properly excluded from scenarios. Those factors under the control of decision-makers, such as shifts in Corps of Engineers policy, are also excluded from scenarios.

Another purpose of scenarios is to provide some idea of the range of possible future outcomes regarding water transportation use. Since many events that may occur in the forecast period are not known with certainty, an analysis of future water transportation use must include a number of possible future courses of these events.

Finally, scenarios group consistent and probable sets of events in order simultaneously to evaluate their impact on waterway transportation use.

Thus, scenarios as used in the NWS are an important tool for strategic planning. They are designed to simplify the planning process. They do this by articulating a set of logical and consistent projections for the future transportation use of the waterways.

(b) Overview

The four NWS scenarios have been defined in a way to reflect the broad range of factors that might be expected to influence the future use of the national waterways. The NWS scenarios reflect:

1. A range of industry growth and transportation use.

2. A range of energy price increases and fuel supplies.

3. Broad options for government investment in the economy.

Consideration of these factors represents part of the analysis that went into the development of the initial concepts for the four NWS scenarios. For example, the need to reflect a range of industry growth suggests that there should be a scenario with a "high" water transportation use and another scenario with a "low" water transportation use.

The four NWS scenarios are:

- Baseline.
- High Water Transportation Use.
- Low Water Transportation Use.
- Bad Energy.

The baseline scenario is a set of events or factors that represents a continuation of present conditions and long established trends. The high use scenario is a set of events or factors that results in higher levels of use of all transportation modes, including water. The low use scenario is the opposite of the high use scenario. The bad energy scenario is a set of factors or events that results in relatively high energy prices and tight supplies of foreign fuels.

An important distinction between scenarios and sensitivity is that NWS scenarios are realistic projections or estimates of alternative future conditions based on a consistent macro view of the world, while sensitivity analyses of projected use are either adjustments to test key assumptions or to incorporate variations in local conditions brought out in the November 1980 public meetings not captured by the NWS approach.

(c) Scenario Development

These four NWS scenarios were developed in a series of stages.

1. Factors Affecting Water Transportation Use. The first stage involved identifying those factors that affect water transportation use. These are:

(a) Macroeconomic factors.

(b) Industry factors (including energy policy).

Macroeconomic conditions refer to broad fiscal and monetary policies that result in differing levels of industrial and public activity in the United States economy.

Industry factors refer to one or more key factors such as energy or environmental policy as well as industry trends that can be expected to influence the level of activity of each of the seven primary waterway user industries. These industries have been identified as: agriculture, fertilizer, steel, petroleum, coal, chemicals, and forest products.

Originally, this list of factors also included changes in:

(a) Transportation systems (waterway physical operating conditions and modal competition).

(b) National transportation policy (federal regulation, expenditure, and cost recovery).

(c) Water resources policy.

(d) Environmental policy (other than those environmental policies that directly affect the seven major waterway industries and that have been properly incorporated in the industry assumptions).

Assumptions about changes in transportation systems were not varied across scenarios. A "low water flow" (i.e., a reduced amount of water in channels) scenario was explictly rejected as a scenario, because it was not possible to state with precision what the relationship would be between specific hydrological conditions and channel depth on the Lower Upper Mississippi, the single analytical segment with major commercial traffic and historical water flow problems.

Assumptions about modal competition were also not varied across scenarios, but industry wide modal shifts were incorporated when historical trends or new flows justified their inclusion.

Assumptions about transportation policy were also not varied across scenarios. Rail and truck deregulation was assumed to take place in all four scenarios. As a result of rail deregulation and the improving financial position of United States railroads, the waterborne share of existing chemical traffic that is water competitive was reduced. Truck deregulation is not expected to affect waterborne commodity flows significantly.

Differences in federal expenditures with regard to the waterways are explicitly incorporated in the NWS strategies (see the Element L final report, Evaluation of Alternative Future Strategies for Action), and the ongoing Section 205 study has as its principal purpose the study of alternative waterway user charges.

Assumptions about other water uses were not varied across scenarios, because prior technical work performed by Element G found that there were no nationally significant conflicts between transportation and other water uses. Finally, environmental policy changes are incorporated as a sensitivity analysis (see the Element L report, Evaluation of Alternative Future Strategies for Action), concerning both the choice of actions that can be taken for commercial navigation and the costs of these actions.

2. Conditions for Each Factor Affecting Use. Once the significant factors affecting water transportation use were identified, it was necessary to determine the explicit conditions that might exist under each general category of scenario assumption.

Under the "macroeconomic" assumptions, three macroeconomic forecasts (TRENDLONG 2003, LARGER GOVT 2003, and BAD-ENERGY 2003) were developed by Data Resources, Inc. (DRI). These forecasts, in turn, were formulated by specifying different values for a number of fiscal and monetary parameters in the Macro Model of the United States Economy. A complete description of the analysis and methodologies underlying the three macroeconomic forecasts can be found in the NWS Element B report, Traffic Forecasting Methodology and Unconstrained Flow Projections.

Different assumptions were also developed for each United States industry using waterborne transportation.

3. Specifying Scenario Assumptions. The third stage in developing NWS scenarios involved assigning values or choices to each major category of assumptions under all four NWS scenarios. Table III-1 presents the principal assumptions for each of the four NWS scenarios and sensitivity forecasts. A number of other assumptions were made in the development of the baseline scenario. However, the assumptions noted in Table III-1 are those that have been explicitly modified in the development of the other three scenarios.

Table III-1

THE NATIONAL WATERWAYS STUDY

PRINCIPLE ASSUMPTIONS FOR NWS SCENARIOS

PRINCIPAL ASSUMPTIONS	BASELINE	HIGH USE[1]	LOW USE	BAD ENERGY	DEFENSE	HIGH COAL EXPORTS
1. MACROECONOMIC	TRENDLONG	TRENDLONG	LARGER GOV-ERNMENT	BAD ENERGY	WARTIME ECONOMY[2]	TRENDLONG
2. CORN YIELDS BY 2003 (BUSHELS PER ACRE)	121	121	110	121	121	121
3. WEST COAST SHARE OF FARM PRODUCTS EXPORTS	14%	14%	14%[3]	14%	OVERALL DECLINE DURING CONFLICT	14%
4. PHOSPHATE EXPORTS	DECREASE AFTER 1985	CONSTANT AFTER 1985	DECREASE AFTER 1985	DECREASE AFTER 1985	CONSTANT AFTER 1985	CONSTANT AFTER 1985
5. STEEL IMPORTS (PERCENT OF TOTAL CONSUMPTION	DECREASE AFTER 1990 from 17% to 15%	DECREASE AFTER 1990 from 17% to 15%	INCREASE TO 26% BY 2003	DECREASE AFTER 1990 FROM 17% TO 15%	DECLINE SHARPLY DUR-ING CONFLICT	DECREASE AFTER 1990 FROM 17% TO 15%
6. CRUDE OIL PRICES (AVERAGE ANNUAL PRICE INCREASE)	3.8%	3.8%	3.8%	4.8%	3.8%	3.8%
7. CRUDE OIL IMPORTS BY 2003 (MILLIONS OF TONS)	290	290	240	200	DECLINE OF 100 MILLION TONS PER YEAR DURING CONFLICT	290
8. COAL EXPORTS BY 2003[4] (MILLIONS OF TONS)	107	156	107	156	156	290[5]
9. GULF COAST SHARE OF TOTAL COAL EXPORTS IN 2003[4] (PERCENT)	19%	23%	11%	23%	23%	35%
10. DOMESTIC COAL CONSUMPTION BY 2003 (MILLIONS OF TONS)	1,794	2,360	1,625	1,728	2,360	2,360
11. SYNFUEL PLANTS ON WATER (COAL CONSUMPTION IN MILLIONS OF TONS BY 2003)	10 (50)[6]	11 (61)	6 (30)[6]	15 (81)	11 (61)	11 (61)
12. COAL SLURRY PIPELINES	NONE	NONE	NONE	7[7]	NONE	NONE
13. EASTERN COAL USE (DOMESTIC LAKE ERIE LOADINGS OF COAL BY 2003 IN MIL-LIONS OF TONS)	PRESENT TECH-NOLOGY AND REGULATIONS (20)	PRESENT TECH-NOLOGY AND REGULATIONS (22)	INCREASED USE IN GREAT LAKES AREA (24)	PRESENT TECHNOLOGY AND REGULATIONS (20)	PRESENT TECHNOLOGY AND REGULA-TIONS (22)	PRESENT TECHNOLOGY AND REGULA-TIONS (22)

NOTES:
(1) The Miscellaneous Sensitivities forcasts incorporates all the assumptions of the High Use Scenario. All the adjustments to the Miscellaneous Sensitivity forecasts are adjustments to account for database errors or to introduce alternative regional forecasts.
(2) Based on Federal Emergency Management Agency forecast.
(3) Great Lakes share drops 10%.
(4) Overseas and Canadian destinations.
(5) Based on National Coal Association forecast as modified by DRI.
(6) An additional demonstration plant (not included in these numbers) on the Mononganela is operated from 1983 to 1990 and consumes 3,000,000 to 6,000,000 tons of coal each year. However, after 1990, it is discontinued.
(7) One of these seven pipelines (ETSI) will divert 4.5 million tons of coal from the waterways by 2003.

SOURCE: Appendix A

(d) Scenario Descriptions

Each scenario along with its major assumptions which were finalized in the fall of 1980 is discussed below.

1. Baseline Scenario. In general, the baseline scenario incorporates factors as they are now or as they have changed according to well established trends in the past. The baseline scenario is not considered to be a "more likely" scenario. Rather it is more a benchmark scenario. Past trends are unlikely to continue without some change.

The baseline scenario is based on the DRI macroeconomic projection entitled "TRENDLONG 2003." Its principal assumptions include:

(a) A fertility rate that approaches 2.1 children per woman (a level that is consistent with zero population growth).

(b) A small reduction in the mortality rate for all age groups.

(c) Economic recovery in 1981 and 1982 from a 1980 recession.

(d) Corporate and personal income tax cuts in 1981 of $10 billion.

(e) A public sector that grows no faster than the rate of growth in GNP.

These assumptions, and all the assumptions described below, are not simply assumptions designed to fit NWS. Rather they represent a coherent consistent view of the world, taking into account all sectors of the economy. While the level of abstraction is high, the approach nevertheless generates comprehensive projections of water

transportation use simultaneously accounting for different levels of macroeconomic activity, the different parts of the navigation system, their relationship to one another, and to other modes.

A number of industry assumptions are made in the baseline scenario. This scenario assumes that export demand for grain will continue to show strong growth, averaging 4 percent per year from 1977 to 1990 and 3 percent per year from 1990 to 2003. During this time, domestic grain consumption remains relatively constant. Because of restrictions on cropland, the acres planted in grains grow relatively slowly, from an average 254 million acres in 1974-1978 to 275 million acres in 1999-2003.

Cultivating additional cropland causes some of the increases in production, but most result from increased yields. Corn acreage harvested rises from 70.9 million in 1977 to 77.7 million in 2003, wheat acreage from 66.5 to 72.2 million, and soybean acreage from 57.6 to 77.9 million. Meanwhile the average corn yield rises from 91 to 121 bushels per acre, the wheat yield from 31 to 42 bushels per acre, and the soybean yield from 31 to 38 bushels per acre. The projected 32.8 million acre increase in corn, wheat, and soybean harvests will come from increased utilization of marginal and set-aside lands, from land diverted from other crops, and from increased double-cropping. Normal expected levels of erosion are also built into the forecasts.

The agriculture industry model assumes that new hybrids and improvements in farming techniques will continue to increase yields and that the average climate in major grain-producing regions will not change for the worse. The assumption that average yields will increase is based on substantial improvements in yields over the past decade, particularly for corn and soybeans, but it carries risks. Unexpectedly poor weather can dramatically reduce yields, and if expected progress in developing higher-yield varieties fails to materialize, less grain will be produced.

The principal assumptions regarding the steel industry are that growth in world steel demand reduces excess foreign steel capacity and that the United States is required to increase its own domestic steel capacity by

enactment of tax and depreciation changes favorable to the domestic steel industry. As a result, imports as a percent of total consumption decrease after 1990 from 17 percent to 15 percent by 2003. A second key factor in the steel industry projections relates to an estimate that direct reduced iron will fill the gap between scrap supply and demand at a price of $110 per ton, the current estimated cost of direct reduced iron.

The principal energy assumptions are that the real price of foreign crude oil will increase at an average rate of 3.8 percent and that domestic oil and gas prices will be gradually decontrolled. (1) Partly as a result of these price increases, crude oil imports fall from the 1977 levels of 405 million tons to 290 million tons by 2003.

The forecast for United States energy consumption over the next 25 years is characterized by substantially slower growth for petroleum fuels due to high price and supply availability problems. In general, the petroleum share of total energy consumed falls from 37 percent in the autumn 1979 forecast to 33 percent in the Spring 1980 analysis.(2) Total energy use fell by approximately 11 percent in the Spring 1980 forecast (relative to the Autumn 1979 forecast), while petroleum consumption decreased 21 percent by the year 2003.

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1 Price controls were in fact removed by President Reagan in 1981. Other controls were still in place at the time this report was prepared. The analysis would be no different if the lifting of controls had been precisely predicted.

2 The original (Autumn 1979) NWS waterborne petroleum forecast was done prior to the energy price increases in 1979 that resulted in a dramatic shift downward in United States petroleum fuel use. In order better to reflect the future outlook for oil demand and waterway petroleum traffic based on new price/quantity relationships, a new energy forecast (Spring 1980) was prepared for the final evaluation stages of NWS.

Although energy savings in 1979 and 1980 have been quite dramatic, the reductions have been aided by a slow-growth economy and a mild winter in 1979. Obviously, a good portion of the savings thus far have accrued from one-time benefits. Thermostats can be significantly lowered in the future only by those households that were well-heeled enough to avoid doing so in the past. Conversely, a large percentage of energy savings can be accomplished with the passage of time. The bulk of today's housing stock, passenger car fleet, and industrial capital stock was designed and constructed in a low-priced energy era. The oil price shocks of 1973 and 1979, and the yet-to-come domestic oil and natural gas price decontrol of the 1980s will provide a tremendous incentive to upgrade the energy efficiency of existing capital stocks in all sectors.

Energy pricing will play a crucial role in determining fuel consumption patterns over the next twenty-five years. New contract prices for coal are expected to show real growth comparable with OPEC oil through 1990, but gradually decline to less than half the OPEC rate as the average OPEC oil price accelerates in the 1990s. New contract coal starts from an oil-equivalent price of $9.11/barrel in 1980, or 26 percent of delivered foreign crude. By the year 2000, the oil equivalent price of coal in 1980 dollars is $14.62/barrel, or 21 percent of delivered foreign crude. This slowly-widening, long-term gap should provide ample incentives to foster the strong projected shift to coal and more than cover the high capital and operating costs associated with the tough environmental regulations governing its use.

Real electricity price growth for the 1980 to 1990 period, at roughly 2.5 percent annually in real terms, is approximately 80 percent of the real OPEC growth rate. The relatively high coal price growth rate during this period, plus domestic oil and gas decontrol, are contributing factors. During the 1990s, slower growth in coal prices, combined with the absence of a decontrol growth component for oil and gas, lead to electricity price growth of roughly 0.5 percent annually in real terms.

The present forecast of total domestic crude oil production is unchanged from the earlier forecasts for 1990 but about 6 percent lower for the year 2000. Most of this decline reflects increasing pessimism about the prospects for "new" oil. Similarly, lower-48 natural gas production is almost unchanged from the prior forecast through 1985 but follows a 2 percent to 5 percent lower path thereafter, again based on lower finding rates. The more pessimistic drilling outlook occurs despite slightly higher real wellhead netbacks (after excise tax) in the 1990 to 2000 period. Despite the lower domestic oil supply, total petroleum imports are down to the 5.5 mmbd to 6.0 mmbd range for 1990 to 2000 as compared with 6.5 mmbd to 7.0 mmbd in the earlier forecasts as a result of lower petroleum demands.

The required long-term supply of coal is down slightly in response to slightly lower economic and electricity growth rates. The level of nuclear power is expected to be down slightly by the end of the forecast period for the same reasons.

Table III-2 shows the expected growth for certain key energy ratios. As in prior forecasts, the ratio of energy to real GNP growth is expected to average about 55 percent for the 20-year period, showing a gradual upward shift in later years as the opportunities for energy efficiency gains become less dramatic and energy intensive production of alternative energy sources gains momentum.

The industrial sector is expected to demonstrate continued reductions of both fossil fuel and electricity consumption per unit of industrial output throughout the forecast period. The rate of efficiency gain diminishes gradually over time. The rate of electricity use per unit of industrial output is expected to show a far weaker rate of decrease than the corresponding fossil fuels ratio. Some substitution of electricity for oil and gas is expected as slower electricity price growth increases electricity's competitive position. A similar fossil fuel to electricity shift is evident in the relative rates of growth on a per-housing-unit basis.

Table III-2

Expected Growth for Key Ratios, Baseline Scenario

	1980-1990	1990-2000
GNP growth	3.2	2.2
Total energy growth	1.5	1.5
Ratio of energy/GNP growth	0.47	0.68
Growth rate in Btu's per $1972 GNP	-1.6	-0.7
Per capita energy use	0.6	0.8
Non-electric energy per unit industrial output	-3.2	-2.7
Electric energy per unit industrial output	-1.2	-0.6
Non-electric energy per housing unit	-0.8	-0.2
Electric energy per housing unit	1.7	1.2

SOURCE: Appendix A.

Total domestic demand for bituminous coal will increase from 617.2 million tons in 1977 to 1,794.0 million tons in 2003, an average annual compound growth rate of 4.2 percent. This growth can largely be attributed to new demand within the synthetic fuel industry as well as significant conversions from oil-fired boilers to coal by utilities, predominantly in the New England and Middle Atlantic regions.

A total of ten synthetic fuel plants is assumed to locate along the Mississippi River and the Gulf of Mexico by 2003 under the Baseline scenario, each consuming 5 million tons of coal by that year. Specifically, three synfuel plants are assumed to locate on the Middle Mississippi (mouth of Missouri River to mouth of Ohio River) while five plants are assumed to locate in the Baton Rouge-New Orleans area and two plants will be located on the Texas Gulf Coast from Calcasieu River to Corpus Christi.[3] These locations were chosen for their proximity to the chemical industry, which is assumed to use a significant amount of synthetic fuel as feedstock. Conversions are assumed to take place primarily in the mid-1980s with specific plants converted according to the Department of Energy's "Phase I: List of Power Plants for Statutory Prohibition." The Burlington Northern railroad is also assumed to gain some of this coal traffic moving to the Gulf Coast West as a result of its merger with the St. Louis-San Francisco railroad.

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3 Under both the baseline and low use scenarios, it is assumed that a demonstration synfuel plant on the Monongahela begins to consume about 3,000,000 ton of barge-delivered coal from Upper Ohio origins in 1983. These increase to 6,000,000 tons in 1990 before being discontinued altogether.

Coal exports (both overseas and Canadian) will increase from 56 million tons in 1977 to 107 million in 2003, displaying an average annual compound growth rate of 2.7 percent. Steam coal exports will account for approximately 48 percent of total exports by the year 2003. In addition, the historical trends in port shares for export coal will continue through 2003. In 1977, 86 percent of total overseas coal exports moved through ports on the East Coast while 13 percent were exported through the Gulf. In 1969 these shares were 99.4 percent for the East Coast and 0.4 percent for the Gulf ports. By 2003, the shares are expected to shift significantly due to the new development and expansion of facilities at the Gulf, facilitating exports of Midwestern and Western coal. In 2003, 50 percent of total overseas exports will move through the East Coast ports while the other 50 percent will move through the Gulf. Approximately 19 percent of total coal exports (including both overseas and Canadian) will move through the Gulf by 2003.

Given the substantial dependence of the chemical industry on petroleum, both as a fuel and feedstock, any revisions in the outlook for petroleum modifies chemical forecasts as well. In addition, the completion of the BN/Frisco railroad merger in the early 1980s is expected to result in more rail/barge competition for chemicals traffic.

2. High Use Scenario. The primary change in the high use scenario from the baseline scenario is an increase in demand for coal. Domestic coal demand increases due to the termination of construction plans for new nuclear power plants. All nuclear plants with construction less than 40 percent complete by mid-1979 are not allowed to come on-line and are replaced by coal-fired generating plants. Total domestic coal consumption increases to 2,360 million tons by 2003. This is a 32 percent increase over the baseline scenario.

One additional synfuel plant is assumed to be in full operation under this scenario. A synfuel plant on the Monongahela River is assumed to use 11,000,000 tons of coal each year from Upper Ohio origins after completing a demonstration phase in 1990.

Coal exports are also higher under this scenario. Exports reach 156 million tons of coal by the year 2003. The share of steam coal exports is expected to increase to 65 percent in 2003. The port shares of coal exports are assumed to remain almost the same as in the baseline scenario, with Gulf ports gaining a slightly higher share of total coal exports by 2003 (namely 23 percent) relative to the baseline scenario.

Finally, phosphate exports from Florida increase to 1985 and remain constant throughout the study period, in contrast to the baseline scenario, which projects a decline after 1985.

3. Low Use Scenario. The low use scenario assumes that government spending as a percent of GNP increases from 32 percent in 1981 to 36 percent in 2003. This higher growth in the public sector reduces industrial growth and, as a result, domestic coal consumption at 1,625 million tons is off 9 percent by the year 2003 from the baseline scenario.

Crude oil imports are also significantly below those of the baseline scenario. An estimated 240 millon tons of crude oil are imported in 2003 (this represents a 17 percent decline from the baseline scenario).

The lower industrial growth of this scenario is complemented by a reduction in the number of synfuel plants on water (only six plants are built on water). The reduction in plants from 10 to 6 takes place in the Lower Mississippi and the Gulf Coast West areas.

Total coal exports are equivalent to the amount exported under the baseline scenario. However, the Gulf Coast port share of total coal exports is lower than under the baseline. The share of Gulf Coast ports increases from 9 percent in 1977 to 11 percent in 2003, but remains well below the 19 percent share in 2003 under the baseline. The Gulf of Mexico coal export facilities are assumed to be the marginal handlers of coal, gaining share when demand is

high but losing share when demand is low. A good deal of the coal moving through the East Coast ports is under long-term contract and will continue to move under either a high demand or low demand scenario. Coal moving through Gulf ports, however, will be new demand and, therefore, will be more prevalent when total demand is high[4].

Finally, it is assumed that changes are made in the regulations affecting the burning of Eastern coal and, as a result, utilities in such states as Michigan burn more Eastern coal at the expense of Western coal. Some of this Eastern coal is shipped by rail, but an additional 4 million tons (relative to the baseline scenario) are shipped from Lake Erie ports by 2003. This Eastern coal replaces Western coal shipped by rail to Lake Superior and from there by vessel to Lake Huron. In addition, some tonnage is taken off the Ohio River to reflect a lower demand for water transportation as a result of an increase in Eastern coal delivered by rail and truck at the expense of Western coal delivered by barge.

The low use scenario makes two other assumptions that differ from the baseline. First, the growth in corn yields increases from 91 bushels in 1977 to only 110 bushels in 2003. As a result, corn exports are 3.65 billion bushels by 2003, a 16 percent decline from the baseline scenario. As a result of the lower grain exports,

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4 In order to account for this under the low demand scenario, coal exports are held at the 1977 levels for the Gulf Coast West (18,000 tons) while the Baton Rouge share is decreased from 20 percent of overseas exports in the baseline scenario to 10 percent under this scenario. In addition, the Mobile River and tributaries share of overseas exports is reduced from 19 percent under the baseline scenario to 15 percent in this scenario. Therefore, total Gulf port share will be 11 percent of total exports (29 percent of overseas exports) compared to 19 percent under the baseline scenario and 23 percent under the high demand scenario.

the share for Great Lakes ports declines about 10%. This assumption is in keeping with the view of several grain companies that the Great Lakes system acts as a residual supplier of elevating capacity. During periods of lower demand, its use would be expected to fall more than proportionately.

Secondly, there is a substantial increase in steel imports as the domestic steel industry fails to add new capacity. The import share of total consumption increases to 26 percent by 2003. The baseline assumes that the import share will be 15 percent by 2003. The increase in steel imports results in higher shipments of iron and steel products at ports and selected inland segments, but a decrease in iron ore shipments on the Great Lakes.

4. Bad Energy Scenario. The bad energy scenario assumes that oil prices will rise faster (4.8 percent annual increase in the real price of world crude oil prices) and that foreign crude oil supplies will be tighter than under the baseline scenario. The increase in oil prices is the driving force in the macroeconomic projection used for this scenario. Foreign oil imports decline to 200 million tons by 2003, a level that is 31 percent below the baseline scenario.

In view of the higher crude oil prices, United States coal exports are also assumed to be higher. Approximately 156 million tons of coal are exported by 2003, of which about 101 million tons are steam coal. The Gulf Coast share of total coal exports increases to 23 percent by 2003.

Fifteen synfuel plants on water are assumed to be built - five more than under the baseline scenario. Two additional plants each are built on both the Baton Rouge to Gulf and the Gulf Coast West areas. The other synfuel plant is on the Monongahela River, where a demonstration plant projected to be operational in 1983, is assumed to go into full production after 1990.

This scenario also assumes that seven coal-slurry pipelines are built. The Energy Transportation Systems, Inc. pipeline, which will move coal from Wyoming to Mississippi at a rate of 35 million tons per year, is the only pipeline expected to reduce water-borne coal flows. An estimated 4.5 million tons of coal will be diverted from water to pipe in 2003. Of this total, 2.5 million tons would have originated on the Lower Upper Mississippi and another 2.0 million tons would have originated on the Upper Mississippi for shipment to the New Orleans area and to utilities in the northern part of the State of Mississippi.

TOTAL TRAFFIC FORECASTS BY SCENARIO

Since the process of scenario development encompassed all economic activity and all modes of transportation, projected use was also developed for other modes, although none of these forecasts was as detailed as the forecasts of water transportation use and none was reported in the Element B Report (Traffic Forecasting Methodology). Projections for selected surface modes for the baseline scenario were presented in the September 1980 Public Forum and these are shown in Table III-3 below.

Table III-3

Projected Use for Selected Surface Modes of Transportation, Baseline Scenario

Mode	Millions of Tons 1977	2003	Change	% Change
Rail	1,391	2,619	1,228	88
Water - Domestic	976	1,452	476	49
Water - Foreign	939	1,133	194	21
Pipeline	1,172	1,401	229	19
TOTAL	4,478	6,601	2,123	

SOURCE: Data Resources Inc.

As can been seen from Table III-3 rail tonnage is expected to grow most rapidly, gaining a national market share, compared to the modes competing for bulk commodities. Thus, the increases in water transportation use will not, in the aggregate, come at the expense of the railroad industry.

Table III-4 summarizes the total waterborne commodity flow forecasts for the four NWS scenarios. Overall, a range of 15 percent in total tons separates the high and low scenarios by the year 2003.

Table III-4

Total Waterborne Commodity Flow Projections by Scenario (Millions of tons)

	1977	1980	1990	2003	Annual Compound Rate of Growth
Baseline	1,915	2,079	2,238	2,586	1.2%
High Use	1,915	2,094	2,297	2,727	1.4%
Low Use	1,915	2,063	2,152	2,380	0.8%
Bad Energy	1,915	2,095	2,278	2,514	1.1%

SOURCE: Appendix A.

Compared to a 0.6 percent annual average compound growth rate for the 1969 to 1977 period, domestic waterborne commodity traffic is expected to increase by 1.2 percent per year under the Baseline Scenario to year 2003. Total United States exports growth in tons slows in the forecast period, averaging 2.5 percent per year to year 2003, compared to 4.2 percent per year from 1969 to 1977. United States imports in tons, led by falling crude oil imports, decline by 0.3 percent per year to 2003, relative to an 8.6 percent per year increase from 1969 to 1977. Exhibit III-2 presents a summary of historical waterborne traffic by NWS reporting region.

Table III-5 indicates that the fastest growing waterborne commodities, namely coal, grain, chemicals, and metallic ores, increase on average between 2.3 percent and 3.4 percent per year through 2003, relative to a 1.2 percent annual growth rate for total traffic in the baseline scenario. The result is a rather dramatic increase in the share of total waterborne traffic in these four commodity groups. They grow from 29 percent of total traffic to 48 percent by the year 2003.

Table III-5

Selected Waterborne Commodity Flow Projections for the Baseline Scenario (Millions of tons)

	1977	1980	1990	2003	Annual Compound Rate of Growth
Farm Products	158	212	251	366	3.4%
Metallic Ores	116	140	176	244	3.1%
Coal	212	239	358	514	3.4%
Chemicals	78	92	108	139	2.3%
Subtotal	564	683	893	1263	3.2%
Share of Total Waterborne Traffic	29%	33%	40%	48%	

SOURCE: Appendix A.

For the high use scenario, coal grows at a 4.5 percent increase per year relative to a 3.4 percent rate in the baseline scenario (see Table III-6). In addition, phosphate rock export growth pushes non-metallic minerals waterborne traffic growth to 1.2 percent per year through 2003, relative to a 0.9 percent increase in the baseline.

Table III-6

Selected Waterborne Commodity Flow Projections by Scenario (Millions of Tons)

	1977	2003 Baseline	2003 High Use	2003 Low Use	2003 Bad Energy
Farm Products	158	366	366	339	390
Metallic Ores	116	244	244	204	235
Coal	212	514	643	476	578
Chemicals	78	139	139	134	136
Subtotal	564	1,263	1,392	1,153	1,339

SOURCE: Appendix A.

The low use forecast has farm products waterborne traffic growth at an increase of 3.1 percent per year to 2003, versus a 3.4 percent rate in the baseline. A lower share (11 percent) of coal exports for Gulf Coast ports, a lower number of synfuel plants, and a partial substitution of rail-delivered coal for water-delivered coal to utilities in Michigan all contribute to the slower rate of growth in waterborne coal shipments. But the overall impact of a faster growing public sector dampens the growth in waterborne shipments (0.8 percent) as well, relative to the baseline (1.2 percent).

Finally, the bad energy scenario has slightly higher coal exports than the baseline, as well as increased grain exports to pay for higher imported oil prices. However, lower economic growth depresses remaining commodity traffic via water, resulting in a 1.1 percent per year growth rate to 2003 for total waterborne flows, compared to a 1.2 percent rate in the baseline.

The forecasts are summarized in Exhibit III-3, first by the 14 reporting commodities and then by the 22 reporting regions. The commodity forecasts are presented in terms of total tons shipped or received. The regional forecasts are presented in terms of tons of total traffic originating, terminating, passing through, and moving within each region. Accordingly, the total regional flows add up to a number larger than the national total since flows through and between regions are attributed to each region involved. The "double counting" of inter-regional flows has been eliminated in the national totals.

For a more detailed presentation of these flows, the reader is referred to Appendix A of this report, published under separate cover. This appendix presents the forecasts for selected reporting regions and the 14 reporting commodities. The forecasts include domestic shipments and receipts in tons; exports and imports in tons; and domestic traffic in tons and ton-miles.

SCENARIO DIFFERENCES BY COMMODITY

Five key commodity groups -- coal, petroleum, chemicals, grain, and iron and steel -- are responsible for the major differences in waterborne commodity flows by scenario. This sub-section analyzes how the scenarios differ on a commodity basis. While differences are discussed here in terms of variations from the baseline scenario, it is not meant to imply that the baseline scenario has greater validity or a higher probability of occurrence than the other scenarios. The comparisons are discussed in this way only for ease of exposition.

(a) Coal

1. Baseline Scenario. Coal is one of the primary commodities underlying waterborne traffic growth in the forecast period. Domestic coal tonnage under the baseline scenario is expected to grow by 3.4 percent per year from 1977 to 2003, with its share of total traffic increasing from 11 percent in 1977 to 19 percent by 2003.

Total domestic shipments increase from 156.3 million tons in 1977 to 403.1 million tons in 2003 under the baseline scenario. This is an average annual growth rate of 3.7 percent. Those segments which experience the most growth are those which have synfuel plants locating on them or which have utilities converting from oil to coal. Therefore, the Baton Rouge to Gulf reporting segment, the Gulf Coast West reporting segment, and the Middle Atlantic Coast reporting segment all experience significant tonnage growth over the 26-year period.

As discussed above, total exports increase from 54 million tons in 1977 to 107 million tons in 2003. Exports to Canada via the Great Lakes accounted for 31 percent of total exports in 1977 and are expected to increase their share to 36 percent by 2003. The major development in exports under this scenario, however, is the shift in port shares. This shift to increased use of Gulf ports results in exports through those ports increasing from 5.1 million tons in 1977 to 20.6 million tons in 2003, an average annual compound growth rate of 5.5 percent.

Total domestic traffic increases most rapidly for those segments which had small tonnages in 1977 (e.g., the Arkansas River and the Gulf Coast West). Major river segments such as the Ohio River, the Tennessee River, and the Mississippi River experience more conservative growth rates (except where synfuel plants locate). Domestic traff c on the Great Lakes also experiences rather slow growth rates of 1.8 percent per year from 1977 to 1990 and 2.1 percent from 1990 to 2003. The same basic trends are obvious in domestic ton-miles for the major segments.

2. High Use. Total waterborne domestic traffic shipments/receipts increase from 156 million tons in 1977 to 484 million tons in 2003, 81 million more tons than in the baseline scenario. The average annual compound growth rate for this traffic is 4.4 percent. Upper Mississippi shipments, Lower Mississippi receipts, Baton Rouge to Gulf receipts, Gulf Coast West shipments and receipts, and Middle Atlantic Coast shipments and receipts all average compound annual growth rates above 10 percent from 1977 to

1990, again largely due to the demand created by synfuel plants and converting utilities. The annual growth rates fall to the four-nine percent range from 1990 to 2003.

Total coal exports are 43 percent higher under this scenario than the baseline and will almost triple in 26 years. This is reflected in all of the port growth rates and especially the Gulf ports, which gain market share at the same time that exports experience average annual compound growth rates of 4.2 percent. Imports also increase at significant rates due to the overall increased demand for coal.

Total domestic tonnage and ton-miles also reflect the significant increase in coal flows brought about by a nuclear moratorium. Although some segments experience greater growth than others (regions which would have otherwise relied on nuclear plants), 11 out of the 13 segments with some domestic traffic will have average annual growth rates above four percent from 1977 to 1990 and 8 out of 13 segments have average annual growth rates in total traffic above 4.5 percent from 1990 to 2003. These are extremely strong growth rates.

3. Low Use. Waterborne domestic tonnage is at the lowest level in this scenario of all the scenarios. Total shipments/receipts reach 365 million tons in 2003, 38 million tons less than the baseline (-9 percent) and 119 million tons less than the high use (-25 percent). The average annual compound growth rate for shipments/receipts under this scenario is 3.3 percent. Growth rates for shipments on the Upper Mississippi decline more than a percentage point from 1977 to 1990 compared to the baseline growth rates. Baton Rouge to Gulf reporting segment tonnage also experiences slower growth rates while most of the coal delivered to the Gulf Coast West for the one remaining synfuel plant comes by rail. Ohio River growth rates also slow slightly due to the increased Eastern usage which is assumed to move by rail.

Total exports are the same as in the baseline scenario but the Gulf ports lose some of their share of total exports. Total exports through the Gulf ports only total 12.7 million tons in 2003, compared to 20.6 million tons under the baseline scenario.

The Gulf Coast East segment is the only segment to have average annual growth rates greater than seven percent from 1977 to 1990. Ton-miles reach only [illegible] billion compared to 140 billion under the baseline.

4. Bad Energy. Tonnage is slightly lower during the 1980s due to increased conservation efforts as mentioned before. By the 1990s, however, waterborne traffic reaches tonnage levels above those under the baseline scenario. By 2003, domestic shipments/receipts total 41[illegible] million tons, 11.0 million tons more (2.7 percent) than under the baseline scenario. Major segments to experience increases in receipts are the Baton Rouge to Gulf segment and the Gulf Coast West segment, due to the four additional synfuel plants. By 2003, receipts on the Baton Rouge to Gulf segment total [illegible] million tons, 11 million tons more than under the baseline. Over 35 million tons of this go to the seven synfuel plants located on this segment. Receipts on the Gulf Coast West total 10.5 million tons by 2003, twice as much as under the baseline scenario. This tonnage goes to two of the four synfuel plants located on this segment. The remaining two plants are assumed to be serviced by the BN/FRISCO railroad system.

(b) Petroleum

1. Baseline and High Use Scenarios. Total domestic waterborne movements of petroleum and coal products are essentially flat at nearly 365 million tons during the forecast period, compared to a steady increase in flows during the 1969 to 1977 period. Declining petroleum imports, due to higher oil prices as well as domestic conservation, are the primary reasons behind the levelling-off of petroleum traffic.

The current baseline scenario reflects an approximately 20 percent reduction in waterborne petroleum domestic traffic by the year 2003, relative to the original (Autumn 1979) NWS petroleum forecast presented in the earlier Element B final report, Traffic Forecasting Methodology and Demand Projections.

For domestic waterborne movements of crude petroleum, shifts in coastwise traffic constitute the major changes over the next twenty-five years. Alaskan North Slope oil shipments jump to over 80 million tons by 1980, relative to 15 million tons in 1977, and remain near that level through the year 2003. In a complementary fashion, California Coast oil receipts jump from 22 million tons in 1977 to over 57 million tons by 1980. The remainder of the Alaskan crude oil originations terminate either along the Washington/Oregon Coast (receipts up from 4.8 million tons in 1977 to 17 million tons by 1980) or are transhipped via the Panama Canal to Gulf Coast destinations. Although crude petroleum imports decline in Gulf Coast ports, infusions of Alaskan crude oil keep total receipts and shipments fairly constant.

For crude petroleum imports, total waterborne flows decline about 1.3 percent per year over the next twenty-five years from 405 million tons to 290 million tons by 2003. Major declines in domestic Caribbean flows and Middle Atlantic Coast and Gulf Coast traffic result from the overall decline in United States dependence on foreign crude oil supplies.

Domestic waterborne petroleum and coal product flows experience a steady decline of 1.3 percent per year from 1977 to 2003. Traffic losses are fairly evenly spread across all segments as industrial, utility, and commercial users shift away from petroleum fuels. Gulf Coast West shipments fall from over 81 million tons in 1977 to 61 million tons by 2003, for a decline of 1.1 percent per year on average for the period. Middle Atlantic Coast shipments decline at a rate of 1.7 percent per year from 112 million tons in 1977 to 71 million tons in 2003, reflecting the substitution of coal for oil-fired utilities along the eastern seaboard.

Imports of petroleum and coal products are also expected to decline steadily over the forecast period, falling from nearly 94 million tons in 1977 to just over 35 million tons by 2003, for a compound annual rate of -3.9 percent per year. Middle Atlantic Coast imports fall most dramatically, declining from nearly 47 million tons in 1977 to 17 million tons by the year 2003. Similar

declines are experienced among the North and South Atlantic Coast ports in petroleum product imports. In keeping with present trends, all exports of petroleum products were assumed to fall to zero levels during the forecast period.

2. Low Use Scenario. Table III-7 summarizes the differences by year between the petroleum waterborne flows in the baseline and low use scenarios. The number ".996" implies that total waterborne domestic flows under the low demand scenario are 99.6 percent of the baseline flows. Thus, in the year 2003, domestic and foreign waterborne petroleum traffic in the low use scenario are 93 percent and 91 percent below the baseline scenario.

Table III-7

Differences in Waterborne Petroleum Flows Between Baseline and Low Use Scenarios

Year	Domestic Traffic	Foreign Trade
1980	.996	1.004
1985	.977	.971
1990	.960	.951
1995	.944	.939
2000	.932	.919
2003	.928	.908

SOURCE: Appendix A.

For domestic waterborne crude oil flows, the low use scenario has total shipments of 129 million tons by 2003, compared to 133 million tons under the baseline scenario. The lower petroleum use is primarily due to slower economic growth over the forecast period. The low use alternative assumes that the majority of Alaskan crude oil flows to Gulf coast ports, with the lower petroleum fuel needs resulting in no new West Coast to Midwest pipeline construction activity. Imports of crude oil fall at 2.0 percent per year in the forecast period, declining from 405 million tons to 240 million tons by 2003.

Domestic petroleum product traffic declines to 241 million tons by the year 2003 under the low use scenario, compared to 260 million tons under the baseline case. The coastal receipts and shipments, especially for the East coast ports, experience the most substantial traffic declines over the forecast period. Gulf Coast segments, especially Baton Rouge to the Gulf, also have sharper declines in total shipments than under the baseline scenario, with receipts falling less dramatically.

Domestic waterborne imports of petroleum and coal products fall by 4.2 percent per year (1977 to 2003) under the low scenario, relative to a 3.8 percent decline under the baseline scenario. East Coast ports are most affected by the decline, with Gulf Coast ports experiencing substantial declines as well.

3. Bad Energy Scenario. Table III-8 contains the differences in total traffic levels between the baseline and bad energy scenarios.

Table III-8

Differences in Waterborne Petroleum Flows Between Baseline and Bad Energy Scenarios

Year	Domestic Traffic	Foreign Trade
1980	.999	1.003
1985	.978	.978
1990	.949	.953
1995	.923	.921
2000	.899	.886
2003	.890	.876

SOURCE: Appendix A.

For crude oil domestic waterborne flows, the bad energy scenario has total traffic at 137 million tons by 2003, relative to 133 million tons under the baseline forecast.

As in the case of the low use scenario, most Alaskan crude oil is assumed to be transshipped via the Panama Canal to Gulf Coast ports, although the Northern Tier pipeline is built in the 1980s. Under the bad energy scenario, crude oil imports are forecast to fall to 198 million tons, compared to 290 million under the baseline scenario. Supply problems, high prices and domestic conservation all account for the dramatic reduction in imports. Gulf Coast West crude oil imports are most affected, falling from 119 million tons in 1977 to 53 million by the year 2003. Similarly, activity for the Baton Rouge to Gulf segment falls from 79 million tons to 35 million tons by 2003.

For domestic waterborne petroleum and coal products activity, the bad energy scenario has total flows at 231 million tons by the year 2003, compared to 260 million tons under the baseline scenario. East Coast and Gulf Coast ports experience the majority of the declines relative to the baseline forecast. For petroleum product imports, the bad energy scenario has 31 million tons, relative to 36 million tons by 2003 in the baseline forecast.

(c) Chemicals

1. Baseline and High Use Scenarios. Under the baseline scenario, total domestic waterborne chemical traffic increases from 46 million tons to 94 million tons by 2003, for a compound growth rate of 2.8 percent per year. Major increases in shipments occur from the Gulf Coast West (up 18 million tons by 2003 over 1977), Baton Rouge to Gulf (up 13 million tons through 2003) and the Ohio River (up four million tons to 2003). Gulf Coast West receipts grow 10 million tons to the year 2003, Ohio River receipts grow by 9 million tons, and Middle Atlantic receipts increase from 5 to over 10 million tons by 2003.

Foreign trade chemical traffic to the year 2003 reflects the increase of United States petroleum prices to world market levels. Imports of chemicals rise from nearly 11 million tons in 1977 to over 18 million tons by 2003, relative to a 5 million ton increase in total chemical exports over the same period. The majority of terminations for chemical imports are along the West and East Coasts during the forecast period.

In sum, impacts on waterborne chemical traffic are most significant on the Gulf Intracoastal Waterway, Lower Mississippi River, Ohio River, and the Warrior River System. In particular, southern and western rail carriers are assumed to be most successful in capturing chemical traffic from barge, primarily on Gulf to Midwest and Gulf to East North Central flows.

2. Low Use Scenario. The forecasts of chemical traffic differ from one another only insofar as the underlying macroeconomic projections cause changes in the growth of chemical production. Table III-9 summarizes the changes in domestic and foreign flows between the baseline and low use scenarios. As can be seen, the differences are negligible and, in any event, are less than six percent.

Table III-9

Differences in Waterborne Chemical Flows Between Baseline and Low Use Scenarios

Year	Domestic Traffic	Foreign Trade
1980	.992	1.032
1985	.994	1.014
1990	.979	1.010
1995	.957	1.006
2000	.951	.998
2003	.944	.992

SOURCE: Appendix A.

Under the low use scenario, total domestic waterborne chemical traffic rises to only 87 million tons by 2003, relative to 94 million tons under the baseline scenario. Shipments from the Gulf Coast West, Baton Rouge to Gulf, and Ohio River chemical facilites grow at a slower rate under the low use forecast relative to the baseline. Similarly, receipts at Middle Atlantic ports, Ohio River, Tennessee River, and Baton Rouge to Gulf plants increase less rapidly under this scenario.

For foreign trade activity, export traffic increases slightly under the low use scenario due to producers seeking foreign markets when domestic chemical demand falls off. Under the low-use alternative, total waterborne chemical exports are one million tons above baseline levels by the year 2003. Similarly, lower economic activity in the United States results in lower chemical imports.

3. Bad Energy Scenario. Table III-10 presents the differences between the bad energy and baseline scenarios for waterborne chemical flows.

Table III-10

Differences in Waterborne Chemical Flows Between Baseline and Bad Energy Scenarios

Year	Domestic Traffic	Foreign Trade
1980	1.001	.989
1985	.996	.941
1990	1.002	.939
1995	.987	.942
2000	.981	.946
2003	.992	.950

SOURCE: Appendix A.

Domestic waterborne shipments of chemicals are not substantially affected under the bad energy scenario, with total tons at 93 million, compared to 94 million tons in the baseline scenario by the year 2003.

Higher United States oil prices under the bad energy scenario result in lower chemical imports, as relative United States/world prices favor United States producers over foreign producers in the United States market. Imports fall off along the East and West Coasts at a slightly higher rate than for Gulf Coast chemical imports.

The bad energy scenario also results in lower export traffic because higher United States oil prices raise chemical prices, reducing foreign demand for United States produced chemicals.

Table III-11

Agriculture Industry Forecasts for the Baseline Scenario
(Million Barrels)

	1977	1980	1985	1990	1995	2000	2003	% Compound Annual Growth 1977 to 1990	1990 to 2003
Corn									
United States Production	6,425	6,304	7,458	7,895	8,671	9,084	9,535	1.6	1.5
Corn Belt	3,471	3,809	4,343	4,326	5,232	5,700	6,080	2.5	1.3
Lakes States	1,068	1,029	1,159	1,214	1,473	1,605	1,697	0.8	2.6
Exports	1,504	2,352	2,825	2,698	3,489	4,135	4,354	4.1	3.7
% Exported	25.0	34.6	37.9	34.2	40.2	45.5	45.7	2.4	2.3
Wheat									
United States Production	2,036	2,199	2,346	2,439	2,518	2,605	2,683	1.4	0.7
Northern Plains	750	919	1,084	1,202	1,314	1,351	1,393	3.7	1.1
Southern Plains	293	271	290	310	319	303	296	0.4	-0.6
Exports	938	1,302	1,396	1,398	1,405	1,462	1,708	3.1	1.5
% Exported	46.0	59.2	59.5	57.3	55.8	56.1	53.7	1.7	0.3
Soybeans									
United States Production	1,762	2,039	2,205	2,369	2,837	2,972	2,839	2.3	1.4
Corn Belt	1,001	1,124	1,274	1,215	1,340	1,290	1,196	1.5	-0.1
Southeast	221	293	353	414	524	605	625	4.5	3.2
Exports	595	833	952	1,075	1,306	1,459	1,540	4.7	2.8
% Exported	33.8	40.9	43.2	45.4	46.0	49.1	54.3	2.3	1.4
Barley									
United States Production	424	361	375	333	345	372	387	-1.8	1.2
Grain Sorghum									
United States Production	793	828	810	831	922	936	884	0.2	-0.4
Oats									
United States Production	751	520	634	629	500	455	443	-1.4	-2.7
Total United States Production	12,192	12,751	13,829	14,597	15,793	16,424	16,770	1.4	1.1

Corn Belt	Illinois, Indiana, Iowa, Missouri, Ohio
Lakes States	Michigan, Minnesota, Wisconsin
Northern Plains	Kansas, Nebraska, North Dakota, South Dakota
Southern Plains	Oklahoma, Texas
Southeast	Alabama, Delaware, Florida, Georgia, Kentucky, Maryland, North Carolina, Tennessee, Virginia, South Carolina

SOURCE: Appendix A.

(d) Grain

1. Baseline and High Use Scenarios. Table III-11 presents a summary of the baseline agriculture industry forecasts. For all three major grains, both production and the percent exported grow. Corn production increases 1.6 percent per year from 1977 to 1990 and 1.5 percent per year from 1990 to 2003, with the percent of the crop harvested in the five Corn Belt states rising from 54.0 percent in 1977 to 63.8 percent in 2003. From 1977 to 2003 exports grow 2,750 million bushels, accounting for 88.4 percent of the growth in production, and, by 2003, 45.7 percent of the crop will be exported.

Wheat production rises more slowly, 1.4 percent per year from 1977 to 1990 and 0.7 percent from 1990 to 2003. Production is less concentrated than corn, but is becoming increasingly concentrated; the six Plains states that produced 51.2 percent of the 1977 crop will produce 62.6 percent in 2003. From 1977 to 2003, export growth will actually exceed production growth by 123 million bushels and, by 2003, 63.7 percent of the crop will be exported.

From 1977 to 1990, soybean production increases the fastest of the three major grains, 2.3 percent per year. But, from 1990 to 2003, the growth rate drops to 1.4 percent per year. Corn Belt production rises 1.5 percent per year to 1990 and then declines slightly as that region concentrates on corn production. The Southeast emerges as a major soybean producing area; its growth in production accounts for 37.5 percent of United States growth and its share of the United States crop rises from 12.5 percent in 1977 to 22.0 percent in 2003. During this period, total United States soybean production rises 1,077 million bushels while exports increase by 945 million bushels; by 2003, exports account for 54.3 percent of the crop.

Barge shipments of farm products are concentrated on six rivers: The Upper Mississippi, Lower Upper Mississippi, Lower Mississippi, Illinois, Ohio, and Columbia/Snake. Between 1977 and 1990, average yearly growth on these rivers ranges from 4.3 percent on the Upper Mississippi to 2.0 percent on the Illinois; between 1990 and 2003, growth ranges from 3.3 percent on the Illinois to 1.6 percent on the Columbia/Snake. Corn,

wheat, and soybean shipments account for almost all growth. Although "other farm products" shipments grow from 2.2 percent to 3.6 percent per year, tonnage of these products remains relatively small. "Other farm products" shipments on the Lower Mississippi, the major inland shipper of these products, constitute only 5.9 percent of that segment's total farm products shipments in 2003.

Major growth in receipts is limited to three regions: Baton Rouge to Gulf, the Warrior System, and the Columbia/Snake. Almost all receipts at Baton Rouge to Gulf are corn, wheat, and soybeans and these grow steadily at 3.2 percent per year. Warrior System receipts are mainly soybean receipts at Mobile; total receipts grow 6.1 percent per year from 1977 to 1990 and 2.8 percent per year from 1990 to 2003. Columbia/Snake receipts are almost entirely wheat receipts in the Portland-Longview regions; total receipts grow 4.2 percent per year from 1977 to 1990 and 1.6 percent from 1990 to 2003.

The farm products demand projections reflect two major market shifts. First, the development of unit train service from Nebraska and western Iowa to Washington and California export regions has caused dramatic growth in corn exports from the Pacific Coast. This, in turn, has caused changes in Pacific Coast wheat exporting patterns. Tacoma has emerged as a major corn-exporting region and wheat that used to flow through Tacoma is being diverted to other Pacific Coast ports. Second, the Southeast is expected to become a major soybean producing region as the Corn Belt concentrates increasingly on producing corn. As a result, shipments on the Warrior River System are projected to grow 7.5 percent per year from 1977 to 1990 as Mobile develops into a major soybean exporting center, and growth on the Warrior from 1990 to 2003 will be exceeded or matched by only two rivers, the Illinois and the Ohio.

These two shifts are expected to have relatively small modal impacts. Whether moving to the Pacific or the Gulf Coast, corn from Nebraska and western Iowa is shipped predominantly by rail because of high barge costs on the Missouri. The modal impact of increased soybean production and exports in the Southeast is less straightforward because historical trends are not good indicators of the impacts of a major production shift, but the information available suggests that barge and rail will share equally in traffic growth in this region.

Virtually all the growth in domestic farm products traffic is a result of growth in the export market for corn, wheat, and soybeans. Shipments of corn, wheat, and soybeans to domestic markets are projected to remain constant, and shipments of "other farm products" account for relatively little tonnage. The largest growth in domestic shipments occurs on the Upper Mississippi which ships an additional 18.2 million tons of farm products in 2003, followed by the Illinois which ships an additional 14.3 million tons. Since most river shipments are bound for the Baton Rouge to Gulf region, the segment loadings increase downstream. Projected ton-miles also reflect this shipment pattern. Growth is greatest on the Lower Mississippi, where ton-miles of farm products increase from 25.6 billion in 1977 to 57.5 billion in 2003, because most shipment from upstream segments pass through the Lower Mississippi on their way to the Baton Rouge to Gulf area. Domestic coastwise and lakewise traffic and domestic ton-miles on the Great Lakes show little growth because most activity on the coasts and lakes is in foreign trade.

In foreign trade projections, all major growth is in exports. Shipments from the Baton Rouge to Gulf region increase by 53.1 million tons, and that region continues to handle the largest share of exports. The Washington/Oregon Coast, California Coast, and Warrior System show exceptionally strong growth from 1977 to 1990 as a result of the markets shifts mentioned previously. The Illinois River (Chicago region) and other Great Lakes also show strong growth but much of this growth occurs beteen 1977 and 1980 and reflects an unusually poor base year. Middle Atlantic Coast exports grow fairly steadily from 3.1 percent to 3.4 percent per year; but after strong growth from 1977 to 1980, exports from the Gulf Coast West and Columbia/Snake grow slowly as a result of slow growth in the world wheat market.

2. Low Use Scenario. Corn production grows more slowly than in the baseline scenario, resulting in decreases in exports, domestic consumption, and the demand for grain transportation. Under the low use forecasts, corn production amounts to 8.6 billion bushels, down from 9.3 billion under the baseline, while exports amount to 3.7 billion bushels, down from 4.4 billion bushels.

Exports of all farm products amount to 167.8 million tons in 1990 and 236.0 million tons in 2003, down from 172.9 million tons and 255.5 million tons, respectively, in the baseline scenario. The percentage declines for all farm products are smaller (-7.6 percent) than those discussed earlier for corn, because production of wheat, soybeans, and other farm products is unaffected by the low use scenario.

Domestic waterborne traffic is also expected to suffer under this scenario relative to the baseline, although the decline is smaller (-7.1 percent by 2003) because of small gains in traffic due to a coastal share shift toward barge-served Gulf and Pacific ports.

3. Bad Energy Scenario. The bad energy waterborne forecast for grain affects United States exchange rates and improves the competitiveness of United States grain exports, resulting in higher flows of grain on the Mississippi River and major tributaries for export. Port shares for export are not significantly changed from the baseline scenario.

(e) Iron and Steel

The underlying assumptions for the steel industry are the same for all scenarios except low use, although levels of industry and transportation activity vary among scenarios due to different paths for the economy as a whole and subsequent regional steel demands.

1. Baseline and High Use Scenarios. In the baseline forecast, steel consumption is expected to follow the broad profile of the economy over the forecast period. In the 1977 to 1980 period, average annual steel consumption growth of only 0.7 percent per year reflects the economic recession of 1980. Steel consumption grows at a compound annual rate of 2.6 percent per year from 1980 to 1990 as business fixed investment moves forward and motor vehicle sales rise. In subsequent years through 2003, the steel consumption growth rate is projected to be approximately 2.0 percent per year, as the economy grows at a 2.5 percent rate, close to its potential path. The total increase in steel consumption from 1977 to 2003 is projected to be 77.2 million short tons, or 71 percent.

Steel imports are forecast to decline from a record 21.1 million tons in 1978 to the 16 million ton range in 1979-1980, then rise gradually to 28.1 million tons by 2003. The import share of apparent consumption, however, is projected to decline from 18.1 percent in 1978 to 15.1 percent by 2003. Within this long-term net decline in import share, there is a temporary rise during the strong demand period of the mid-1980's.

Steel shipments are forecast to increase from 91.1 million tons in 1977 to 160.9 million in 2003, an increase of 76.6 percent, slightly greater than the forecast increase in steel consumption.

2. Low Use Scenario. Under the low use case, domestic steel capability is held at 165 million tons for three years beginning in 1985. The domestic steel prices were increased relative to import prices by the amount needed to pull in enough additional imports to fill the demand-capacity gap. The relative domestic price increase puts the import share up to 23 percent or 34 million tons by 1990, above the baseline's 17 percent and 22 million tons, and to 26 percent or 48 million tons by 2003, above the baseline's 15 percent and 28 million tons.

The direct result of limited capacity and higher imports is lower production and shipment of raw steel. By 1990, in-shipments are 114 million tons in the smaller capacity growth case, 8 million below the baseline case, and by 2003 shipments are 142 million tons, 19 million below the baseline case.

Raw steel production is similarly pushed below the baseline projection levels, totalling 154 million in 1990 (12 million below baseline) and 182 million in 2003 (24 million below baseline). Capacity and capability are consequently lower by similar amounts.

Nearly all the reduction in raw steel production below the baseline case occurs in the electric furnace category. This is reasonable, as electric furnaces constituted the means of capacity expansion in the baseline case. Consequently, the major materials differences are lower direct-reduced iron use in electric furnaces and lower iron ore use for direct-reduced iron. Iron ore

consumption in 2003 is 163 million tons, 36 million tons below the baseline scenario consumption. Consumption of other materials is lower by smaller amounts. Scrap consumption is 128 million tons, 6 million tons below the baseline scenario.

The low use case has some surprising results because of the key role of water transportation with respect to steel imports. In particular, because most steel imports enter the United States by vessel, waterborne primary metals imports are 22 percent higher in 1990 and 40 percent higher in 2003 than under the baseline. Because substantial imports move by barge out of the Lower Mississippi River ports, domestic waterborne steel shipments actually increase by 4.6 percent in 1990 and 8 percent in 2003 relative to the baseline scenario. The increased movements from Lower Mississippi River ports offset the decline in the barge shipments from domestic plants.

These gains are far outweighed by losses in metallic ore traffic due to reduced production. Thus, domestic waterborne metallic ore traffic amounts to 137.4 million tons in 2003 under baseline, but only 131.2 under bad energy and 112.6 million tons under low demand. Further, although the metallic ore traffic losses predominate on the Great Lakes, the domestic traffic gains accrue to inland waterway carriers.

3. Bad Energy Scenario. Consumption under the bad energy alternative is 2.7 percent (5 million tons) lower than baseline in 2003 -- due to its impact on business fixed investment and thus on potential GNP. Steel imports under bad energy are higher than under baseline in spite of the decline in consumption, because higher domestic inflation pushes the import market share to 16.9 percent.

SENSITIVITY ANALYSIS FORECASTS

The National Waterways Study has involved over three years of detailed technical analysis on the present and future condition of the United States waterways system. Since the base waterborne flow forecasts were developed

nearly one and one-half years ago, the study team anticipated that certain changes in underlying explanatory factors could occur between the time traffic forecasts and the evaluation of system capabilities were completed. Further, certain issues relating to projected use, such as wartime needs and errors in original data bases, could not be incorporated into the basic scenarios. Thus, these two issues, plus concerns raised at the November 1980 public meetings, were dealt with as special, or sensitivity analyses. Since the primary issue for the evaluation of the present system was lock capacity it was decided to treat all the sensitivity forecasts as adjustments to the High Use scenario. If these sensitivity adjustments had been applied to the Baseline Scenario, for example, the likelihood of locating additional "stress points" in the system would be reduced.

Three sensitivity forecasts were developed, based in part on recent events. The rapid growth of United States coal exports in 1980, for example, were not included in the four original NWS scenarios. Thus, a High Coal Export Sensitivity Analysis was developed.

Another non-economic set that could affect the waterways system is a possible war that involved the United States. Using a forecast of mobilization requirements by the Federal Emergency Management Agency, impacts on waterborne traffic of a five-year war were developed in a Defense Sensitivity.

Finally, certain specialized conditions on some waterways that were not known at the time of the basic NWS forecast development were included in a miscellaneous sensitivity analysis.

(a) Defense Forecast

The NWS Defense Sensitivity analysis was designed to evaluate the capability of the United States waterways system to handle a national emergency involving an overseas war. Since a national emergency would place extraordinary strains on the United States economy and transportation

system, long-term facilities planning should include an analysis that identifies where capacity shortfalls are likely to occur. The NWS Defense Sensitivity analysis uses the Federal Emergency Management Agency forecast of possible economic (production, consumption, imports, exports) impacts on a five-year overseas war to evaluate effects of United States waterborne traffic levels by region and commodity.

The NWS High Use scenario waterborne flow forecasts were modified to reflect a five-year war on two fronts, beginning in 1985 (an arbitrary choice) and ending 1990. Exogenous factors, such as steel mill production, grain exports, oil imports, among others, were modified to reflect higher or lower levels due to the war economy. Finally, waterborne flows were adjusted to reflect changes in the underlying economic conditions for the war period.

Table III-12 presents a comparison of waterborne shipments by industry under the High Use scenario combined with the defense forecast for 1990. As can be seen Table III-12, the principal industry changes are: 1) Greatly increased steel production. 2) Sharply higher use of petroleum and coal (the high use scenario also has more coal use, but it should be remembered that this is based on a slowdown in the United States nuclear energy program). 3) Reduced exports of farm and food products. Overall commodity flows are nine percent higher under the defense forecast in 1990 compared to the High Use scenario.

Table III-13 presents a comparison of the High Use scenario and defense forecast by region. As can be seen, the single largest increase in traffic occurs on the Great Lakes/St. Lawrence Seaway, followed by Alaska, California Coast, Middle Atlantic Coast, and Ohio River. Small declines take place on a few waterways originating and terminating farm and food products for export.

Table III-12

Year 1990 Unconstrained Waterborne Shipments by Industry for High Use Scenario and Defense Forecast (Millions of Tons)

	High Use	Defense	Difference[1]
Farm Products	251.2	216.5	(34.7)[2]
Metallic Ores	175.9	289.5	113.6
Coal	413.8	409.5	(4.3)
Crude Petroleum	479.1	515.4	36.3
Non-Metallic Minerals	187.1	153.2	(33.9)
Food and Kindred Products	67.2	48.2	(19.0)
Lumber and Wood Products	54.5	50.4	(4.1)
Pulp, Paper, and Allied Products	14.3	14.5	0.2
Chemicals	107.7	129.7	22.0
Petroleum and Coal Products	366.2	473.3	107.0
Stone, Clay, Glass and Concrete Products	25.8	23.3	(2.5)
Primary Metals Products	48.2	46.5	(1.7)
Waste and Scrap	27.2	38.3	11.1
Other Commodities	78.7	91.2	12.5
TOTAL[3]	2,296.7	2,499.6	202.9

NOTES: (1) Difference equals Defense Minus High Use.

(2) ( ) denotes a negative number.

(3) Commodities may not add to total due to rounding.

SOURCE: Appendix A.

Table III-13

Year 1990 Unconstrained Waterborne Shipments by Region of High Use Scenario and Defense Forecast
(Millions of Tons)

	High Use	Defense	Difference[1]
Upper Mississippi	49.7	49.5	(0.2)[2]
Lower Upper Mississippi	115.1	114.6	(0.5)
Lower Mississippi	160.2	163.7	3.5
Baton Rouge to Gulf	427.8	421.9	(5.9)
Illinois Waterway	79.6	98.8	19.2
Missouri River	7.3	7.3	0.0
Ohio River	248.5	277.1	28.6
Tennessee River	44.3	46.8	2.5
Arkansas River	11.5	12.7	1.2
Gulf Coast West	355.1	380.4	25.3
Gulf Coast East	139.7	146.1	6.4
Mobile River and Tributaries	86.9	86.2	(0.7)
South Atlantic Coast	68.0	77.0	9.0
Middle Atlantic Coast	431.2	463.8	32.6
North Atlantic Coast	78.2	87.0	8.8
Great Lakes/SLS/ New York State Waterways	307.0	426.9	119.9
Washington Oregon Coast	116.0	129.8	13.8
Columbia-Snake Waterway	52.9	51.8	(1.1)
California Coast	138.1	174.1	36.0
Alaska	94.3	145.9	51.6
Hawaii and Pacific Territories	17.7	17.7	0.0
Carribean	84.1	86.4	2.3
Eliminate Double-Counting of Inter-regional flows	(816.6)	(965.9)	(149.3)
TOTAL[3]	2,296.7	2,499.6	202.9

NOTES: (1) Difference Equals Defense minus High Use.

(2) ( ) Denotes a negative number.

(3) Regions may not add to total due to rounding.

Source: Appendix A

(b) High Coal Exports

The major run-up in world oil prices in 1979 occured after the initial NWS waterborne coal traffic forecasts were completed. At that time, the substantial increases in the demand for United States coal exports, due both to coal supply problems in other countries and the efforts of European and Japanese energy to convert fuel sources away from oil and gas towards coal, were not anticipated in the original coal forecast. As part of the sensitivity analyses, a new analysis was completed that incorporated the latest projections of potential United States coal exports to the year 2003.

Overall, coal traffic under the high use scenario increases from 212 million tons in 1977 to 643 million by 2003, for a compound annual growth rate of 4.5%. Under the High Coal Export alternative, waterborne coal grows to 805 million tons in 2003 for annual compound rate of growth of 5.5 percent.

Table III-14 presents a comparison of the High Use and High Coal Export forecasts by region for 2003. As can be seen, the regions with the greatest increase in coal shipments include the Middle Atlantic Coast, Baton Rouge to Gulf and Mobile River and tributaries. Sizable shipments take place on the Ohio River, the Lower Mississippi, and Gulf Coast West. Export shipments were also included in the High Coal Export forecast for the West Coast. These shipments were routed through the Washington-Oregon Coast and California Coast NWS Regions. Other West Coast NWS Regions are also likely candidates for such shipments. Thus significant shifts in traditional port shares of coal exports are incorporated into this forecast.

(c) Miscellaneous Sensitivities

During the review by the Corps of Engineers and the general public of the four NWS scenarios (Baseline, High Use, Low Use, and Bad Energy) in September and November of 1980, a number of changes were suggested on certain river segments. These changes were typically the result of an

Table III-14

Year 2003 Waterborne Shipments by Region
for High Use and High Coal Export Forecast
(Millions of Tons)

	High Use	High Coal Exports	Difference[1]
Upper Mississippi	68.7	68.7	0.0
Lower Upper Mississippi	167.3	169.6	2.3
Lower Mississippi	231.0	246.6	15.6
Baton Rouge to Gulf	548.7	591.4	42.7
Illinois Waterway	106.4	106.4	0.0
Missouri River	7.8	7.8	0.0
Ohio River	345.2	359.6	14.4
Tennessee River	79.5	86.4	6.9
Arkansas River	15.0	15.8	0.8
Gulf Coast West	389.0	404.1	15.1
Gulf Coast East	168.2	168.5	0.3
Mobile River and Tributaries	137.4	177.6	40.2
South Atlantic Coast	71.1	71.1	0.0
Middle Atlantic Coast	469.2	514.7	45.5
North Atlantic Coast	68.9	68.9	0.0
Great Lakes/SLS/ New York State Waterways	411.1	411.1	0.0
Washington Oregon Coast	121.2	132.9	11.7
Columbia-Snake Waterway	58.6	58.6	0.0
California Coast	143.6	153.4	9.8
Alaska	86.2	86.2	0.0
Hawaii and Pacific Territories	21.5	21.5	0.0
Carribean	74.5	74.5	0.0
Eliminate Double-Counting of Inter-Regional Flows	(1,062.6)	(1,105.6)	(43.0)
TOTAL[3]	2,727.2	2,889.6	162.4

NOTES: (1) Difference Equals High Coal Exports minus High Use.

(2) ( ) Denotes a negative number.

(3) Regions may not add to total due to rounding.

SOURCE: Appendix A.

on going local study, such as the Bonneville Lock feasibility study on the Columbia River. These studies, as would be expected, captured a level of detail greater than would be captured in a national study such as NWS.

Base on Corps and other comments, this sensitivity analysis involved making the following changes:

1. Increasing Ohio and Monongahela River traffic for under reporting of actual traffic levels in the Waterborne Commerce Statistics published by the Corps of Engineers. The Ohio River Division discovered the errors in the data base and the adjustment involved other inland regions to the extent of any interaction with Ohio River traffic.

2. Increasing Arkansas River traffic in line with other forecasts provided by a variety of sources.

3. Increasing sand and gravel shipments on the Columbia River through Bonneville Lock to reflect potential new flows identified in a study by the Portland District of the Corps of Engineers.

4. Increasing miscellaneous traffic at the Inner Harbor Navigation Canal Lock for underreporting of actual traffic levels in the Waterborne Commerce Statistics. The New Orleans District of the Corps of Engineers discovered the error during the course of project studies of this lock.

The first and fourth changes were made to the base year periods as well as the forecast periods. The second and third changes were made only for the forecast periods.

Table III-15 presents a comparison of the High Use and Miscellaneous Sensitivities forecasts for the year 2003 by region. As can be seen, the biggest changes that were made involved the Ohio River, the Lower Mississippi (due almost entirely to the substantial interaction between these two regions), and the Arkansas River. Total usage nationwide is up approximately two percent over the High Use levels.

Table III-15

Year 2003 Waterborne Shipments by Region
for High Use and Other Sensitivities Forecast
(Millions of Tons)

	High Use	Other Sensitivities	Difference[1]
Upper Mississippi	68.7	[illegible].4	0.7
Lower Upper Mississippi	167.3	[illegible]70.7	3.4
Lower Mississippi	231.0	248.4	17.4
Baton Rouge to Gulf	548.7	5[illegible]0.[illegible]	21.7
Illinois Waterway	106.4	107.2	0.8
Missouri River	7.8	7.9	0.1
Ohio River	345.2	382.9	37.7
Tennessee River	79.5	81.4	1.9
Arkansas River	15.0	26.2	11.2
Gulf Coast West	389.0	391.5	2.5
Gulf Coast East	168.2	177.9	9.7
Mobile River and Tributaries	137.4	141.5	4.1
South Atlantic Coast	71.1	71.1	0.0
Middle Atlantic Coast	469.2	469.2	0.0
North Atlantic Coast	68.9	68.9	0.0
Great Lakes/SLS/ New York State Waterways	411.1	411.3	0.2
Washington Oregon Coast	121.2	121.2	0.0
Columbia-Snake Waterway	58.6	63.7	5.1
California Coast	143.6	143.6	0.0
Alaska	86.2	86.2	0.0
Hawaii and Pacific Territories	21.5	21.5	0.0
Carribean	74.5	74.5	0.0
Eliminate Double-Counting	(1,062.6)	(1,117.3)	(54.7)
TOTAL[3]	2,727.2	2,789.2	68.0

NOTES: (1) Difference Equals Other Sensitivities minus High Use.

(2) ( ) Denotes a negative number.

(3) Regions may not add to total due to rounding.

SOURCE: Appendix A.

HISTORICAL
DOMESTIC TRAFFIC
(1000's Tons)

Commodity: All Commodities

Segment	In/Out	69	70	71	72	73	74	75	76	77	% Growth 69-77
		Years									
Upper Mississippi	Shipped	11,860	12,330	14,736	17,175	18,617	20,609	19,769	22,067	20,619	7.2
	Received	13,976	15,293	15,814	16,735	13,799	14,526	15,751	15,009	16,474	2.1
Lower Upper Mississippi	Shipped	18,714	18,519	18,489	22,191	18,933	22,672	24,168	24,236	23,150	2.7
	Received	10,067	10,631	11,342	10,264	8,007	9,447	8,545	9,422	9,042	-1.3
Lower Mississippi	Shipped	12,039	11,955	11,725	10,662	9,487	11,209	10,169	11,881	11,143	-1.0
	Received	16,334	18,544	19,927	20,750	21,520	23,208	21,783	22,570	24,888	5.4
Baton Rouge to Gulf	Shipped	80,188	84,944	85,788	79,804	73,802	75,324	73,884	74,043	84,315	0.6
	Received	53,149	58,006	60,475	74,621	78,073	83,151	87,126	99,483	99,444	8.1
Illinois Waterway	Shipped	26,793	28,738	28,745	33,280	35,230	33,857	36,380	35,382	32,515	2.4
	Received	35,605	37,757	36,834	38,102	39,187	40,420	38,160	34,584	31,248	-1.6
Missouri River	Shipped	6,076	6,518	6,374	6,125	5,694	6,697	5,288	5,533	5,612	-1.0
	Received	5,996	6,127	5,840	5,651	5,396	6,119	4,758	4,597	4,635	-3.2
Ohio River	Shipped	128,975	131,538	128,595	135,138	129,973	127,998	132,570	136,928	140,253	1.1
	Received	125,514	127,849	128,923	134,686	130,221	130,420	131,073	135,453	134,112	0.8
Tennessee River	Shipped	10,736	11,367	13,539	14,492	13,147	13,335	11,967	12,434	10,493	-0.3
	Received	18,383	18,235	18,297	18,458	18,352	15,710	16,756	16,752	17,459	-0.6
Arkansas River	Shipped	642	3,333	3,598	4,595	3,688	4,679	3,944	5,144	6,636	33.9
	Received	349	3,698	3,734	4,376	4,396	5,389	4,460	5,034	6,816	45.0
Gulf Coast West	Shipped	150,028	160,086	159,671	158,557	147,370	147,029	139,042	142,595	148,136	-0.2
	Received	80,711	77,728	77,222	79,139	77,897	78,806	68,742	66,429	75,159	-0.9
Gulf Coast East	Shipped	19,938	21,741	24,724	28,100	27,581	28,587	29,994	29,856	32,236	6.2
	Received	27,203	29,110	30,120	33,554	34,992	35,476	35,431	36,884	38,641	4.5
Mobile River and Tributaries	Shipped	15,628	15,225	16,385	19,427	21,353	22,203	20,809	23,758	23,871	5.4
	Received	14,028	13,794	15,485	19,691	18,127	19,478	16,894	19,295	20,413	4.8
South Atlantic Coast	Shipped	8,282	9,187	9,369	11,332	13,231	12,437	11,221	13,842	12,464	5.2
	Received	24,192	25,114	25,153	27,616	31,150	30,602	30,730	35,593	37,490	5.6
Middle Atlantic Coast	Shipped	158,415	152,572	161,860	171,365	184,996	175,789	162,838	163,256	159,990	0.1
	Received	187,655	206,992	213,595	213,304	213,218	201,784	188,928	186,030	181,200	-0.4

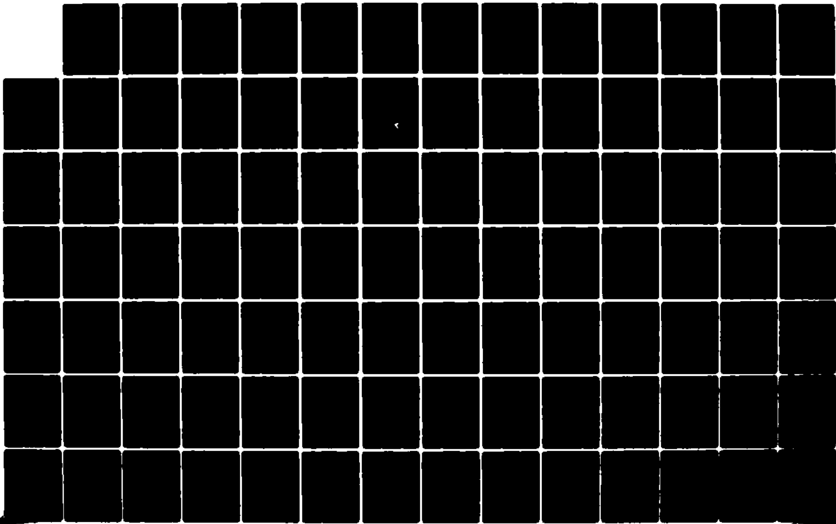
HISTORICAL
DOMESTIC TRAFFIC
(1000's Tons)
(Continued)

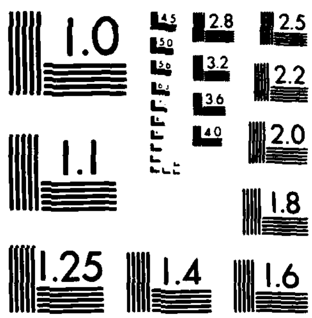
Commodity: All Commodities

Segment	In/Out	69	70	71	72	73	74	75	76	77	% Growth 69-77
		Years									
North Atlantic Coast	Shipped	10,855	11,003	10,937	11,507	11,571	11,836	11,150	10,796	9,914	-1.1
	Received	49,857	48,687	50,559	52,220	48,852	48,168	50,589	51,331	50,273	0.1
Great Lakes and Seaway	Shipped	159,208	157,787	139,295	144,063	155,365	146,145	128,809	132,865	109,590	-4.6
	Received	155,647	154,192	136,349	140,881	151,549	141,890	125,728	129,567	107,660	-4.5
Washington/Oregon Coast	Shipped	32,918	28,609	25,559	26,175	25,308	21,390	21,759	21,062	22,600	-4.6
	Received	32,782	27,602	25,617	23,654	23,678	19,846	19,487	21,173	24,992	-3.3
Columbia-Snake Willamette River	Shipped	12,314	13,580	13,938	15,075	14,702	21,983	22,048	24,617	22,406	7.8
	Received	16,593	17,905	17,702	19,480	18,820	24,888	24,819	26,895	25,848	5.7
California Coast	Shipped	46,880	46,029	42,065	37,833	40,664	37,687	38,441	43,942	43,257	-1.0
	Received	49,772	48,604	45,791	42,586	45,675	43,150	43,695	48,089	50,472	0.2
Alaska	Shipped	13,846	15,316	14,150	14,683	14,579	13,898	12,887	12,874	19,485	4.4
	Received	5,822	6,440	5,657	6,814	6,434	6,667	7,008	7,429	6,077	0.5
Hawaii and Pacific Territories	Shipped	4,658	4,790	4,760	5,555	5,570	4,605	5,806	5,737	5,412	1.9
	Received	7,270	8,463	7,083	7,977	7,095	6,679	6,863	6,520	6,230	-1.9
Domestic Caribbean	Shipped	6,298	18,748	23,117	29,585	34,296	34,912	31,772	33,547	32,405	22.7
	Received	4,387	5,143	5,900	6,160	8,720	9,058	7,386	8,247	7,931	7.7
TOTAL	Shipped	935,290	965,914	957,420	996,718	1,005,158	994,881	954,715	986,396	976,501	0.5
	Received	935,290	965,914	957,420	996,718	1,005,158	994,881	954,715	986,396	976,501	0.5

AD-A127 260 NATIONAL WATERWAYS STUDY: EVALUATION OF THE PRESENT NAVIGATION SYSTEM(U) KEARNEY (A T) INC CHICAGO ILL J EGAN ET AL. MAR 82 DACW72-79-C-0003 2/4

UNCLASSIFIED F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

**HISTORICAL
FOREIGN TRADE
(1000's Tons)**

Commodity: All Commodities

Segment	In/Out	69	70	71	72	73	74	75	76	77	% Growth 69-77
Upper Mississippi	Exports	0	0	0	0	0	0	0	0	0	NC
	Imports	0	0	0	0	0	0	0	0	0	NC
Lower Upper Mississippi	Exports	0	0	5	0	0	0	0	0	0	NC
	Imports	0	0	3	0	0	0	0	0	0	NC
Lower Mississippi	Exports	19	7	43	104	22	0	0	0	0	100.0
	Imports	8	2	8	40	0	0	0	0	0	100.0
Baton Rouge to Gulf	Exports	26,311	33,369	29,870	39,733	46,681	46,982	47,376	59,359	59,920	10.8
	Imports	15,631	16,388	18,575	19,023	26,837	37,233	45,838	66,749	97,255	25.7
Illinois Waterway (1)	Exports	3,825	3,823	3,862	3,206	4,232	2,629	2,723	2,874	2,571	-4.8
	Imports	3,073	3,232	4,041	4,108	2,609	2,611	1,898	3,990	3,573	1.9
Missouri River	Exports	0	0	0	0	0	0	0	0	0	NC
	Imports	0	0	0	0	0	0	0	0	0	NC
Ohio River	Exports	0	0	0	0	0	0	0	0	0	NC
	Imports	0	0	0	1	0	0	0	0	0	NC
Tennessee River	Exports	0	0	0	0	0	0	0	0	0	NC
	Imports	0	0	0	0	0	0	0	0	0	NC
Arkansas River	Exports	0	0	0	0	0	0	0	0	0	NC
	Imports	0	0	0	0	0	0	0	0	0	NC
Gulf Coast West	Exports	20,270	26,944	27,037	28,869	43,527	35,575	35,911	34,000	35,406	7.2
	Imports	14,647	14,739	18,337	19,253	41,047	58,283	66,830	101,541	137,104	32.3
Gulf Coast East	Exports	14,345	14,823	15,058	17,824	18,642	17,252	17,720	18,082	21,499	5.2
	Imports	5,062	5,957	6,347	9,138	10,290	10,924	12,790	17,397	17,622	16.9
Mobile River and Tributaries	Exports	2,504	2,940	2,325	3,054	3,856	3,963	5,405	5,745	5,521	10.4
	Imports	8,206	8,957	8,527	6,674	7,910	9,416	7,896	8,216	8,167	-0.1
South Atlantic Coast	Exports	4,910	5,519	5,426	5,735	6,648	7,364	7,179	7,776	8,618	7.3
	Imports	16,341	18,566	19,940	25,676	28,553	26,251	18,546	20,976	20,701	3.0
Middle Atlantic Coast	Exports	55,909	71,070	52,304	54,761	60,639	72,412	70,757	68,121	56,757	0.2
	Imports	136,736	136,281	136,330	154,222	188,175	178,223	156,194	160,126	168,692	2.7

NOTE: NC = Not calculated

HISTORICAL
FOREIGN TRADE
(1000's Tons)
(Continued)

Commodity: All Commodities

Segment	In/Out	69	70	71	72	73	74	75	76	77	% Growth 69-77
		Years									
North Atlantic Coast	Exports	1,296	1,609	1,147	1,418	1,746	1,573	1,186	1,576	1,307	0.1
	Imports	43,874	50,033	40,624	49,472	53,091	45,996	39,918	38,153	33,997	-3.1
Great Lakes and Seaway	Exports	28,250	32,109	29,620	31,781	34,267	25,490	32,704	32,138	33,765	2.3
	Imports	21,537	20,964	21,928	21,101	25,651	20,732	19,558	26,655	29,255	3.9
Washington/Oregon Coast	Exports	12,306	14,491	12,269	16,371	18,882	17,421	16,144	19,478	18,060	4.9
	Imports	5,940	6,648	7,238	7,624	10,328	12,064	9,866	17,700	20,019	16.4
Columbia-Snake Willamette River	Exports	9,185	10,372	7,849	10,730	14,078	13,611	13,068	14,606	12,821	4.3
	Imports	2,775	2,879	2,602	3,239	3,241	4,245	3,892	3,769	4,045	4.8
California Coast	Exports	18,623	19,799	14,770	13,767	18,246	17,843	17,382	16,856	15,982	1.9
	Imports	38,001	17,579	24,650	31,083	42,304	40,671	40,962	48,431	60,187	5.9
Alaska	Exports	1,137	2,951	2,853	3,681	3,377	3,111	3,239	3,285	5,024	20.4
	Imports	853	1,089	1,102	1,056	1,174	1,735	1,538	1,166	1,619	8.3
Hawaii and Pacific Territories	Exports	120	141	113	216	283	111	143	119	147	2.5
	Imports	4,037	2,946	3,771	4,020	4,339	4,555	4,925	5,547	5,926	4.9
Domestic Caribbean	Exports	2,018	1,329	1,264	1,346	2,194	1,479	1,227	1,639	1,463	-3.9
	Imports	22,872	31,013	37,631	41,922	44,617	44,451	46,106	50,012	51,645	10.7
TOTAL	Exports	201,029	241,296	205,8[illegible]	232,596	277,321	266,816	272,164	285,653	278,861	4.2
	Imports	339,590	337,273	359,65[illegible]	397,661	490,166	497,389	476,748	570,427	659,808	8.7

NOTES: (1) Includes Port of Chicago Great Lakes traffic.

Waterborne Commodity Flow Projections - Baseline
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Farm Products	158.1	212.4	244.4	251.2	298.9	340.0	366.2
Metallic Ores	115.3	139.6	155.1	175.9	199.3	225.7	244.3
Coal	211.8	238.8	303.3	358.3	425.1	482.0	513.7
Crude Petroleum	488.7	534.5	536.5	479.1	477.4	424.8	423.6
Non-Metallic Minerals	159.0	168.1	180.4	183.5	187.8	198.0	197.3
Food and Kindred Products	44.3	49.5	57.1	67.2	74.1	84.7	92.4
Lumber and Wood Products	52.6	55.4	56.5	54.5	53.4	54.5	54.2
Pulp, Paper and Allied Products	11.8	12.2	13.7	14.3	15.0	15.8	16.3
Chemicals	77.8	91.5	102.6	107.7	118.2	131.8	139.2
Petroleum and Coal Products	467.5	440.0	384.8	366.2	342.0	306.4	299.2
Stone, Clay, Glass and Concrete Products	16.2	20.9	23.1	25.8	27.9	30.9	32.8
Primary Metals Products	34.3	33.9	43.5	48.2	52.0	56.1	58.4
Waste and Scrap	21.8	23.8	26.6	27.2	27.7	28.6	29.2
Other Commodities	53.8	57.7	67.5	78.7	91.1	107.1	118.8
TOTAL	1,914.9	2,078.5	2,195.1	2,237.6	2,390.2	2,486.4	2,585.6

Waterborne Commodity Flow Projections - High Use
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Farm Products	158.1	212.4	244.4	251.2	298.9	340.0	366.2
Metallic Ores	115.3	139.6	155.1	175.9	199.3	225.7	244.3
Coal	211.0	254.1	315.0	413.8	495.2	608.7	642.8
Crude Petroleum	488.7	534.5	536.5	479.1	477.4	424.8	423.6
Non-Metallic Minerals	159.0	168.1	188.5	187.1	194.8	208.4	209.8
Food and Kindred Products	44.3	49.5	57.1	67.2	74.1	84.7	92.4
Lumber and Wood Products	52.6	55.4	56.5	54.5	53.4	54.5	54.2
Pulp, Paper and Allied Products	11.8	12.2	13.7	14.3	15.0	15.8	16.3
Chemicals	77.8	91.5	102.6	107.7	118.2	131.8	139.2
Petroleum and Coal Products	467.5	440.0	384.8	366.2	342.0	306.4	299.2
Stone, Clay, Glass and Concrete Products	16.2	20.9	23.1	25.8	27.9	30.9	32.8
Primary Metals Products	34.3	33.9	43.5	48.2	52.0	56.1	58.4
Waste and Scrap	21.8	23.8	26.6	27.2	27.7	28.6	29.2
Other Commodities	53.8	57.7	67.5	78.7	91.1	107.1	118.8
TOTAL	1,914.9	2,093.8	2,206.8	2,296.7	2,467.2	2,623.4	2,727.2

Waterborne Commodity Flow Projections - Low Use
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Farm Products	158.1	212.9	245.8	244.6	283.1	316.0	339.3
Metallic Ores	115.3	130.7	154.1	157.3	172.7	189.4	203.5
Coal	211.8	232.1	294.9	351.6	401.8	448.8	475.9
Crude Petroleum	488.7	527.3	514.5	448.3	429.1	373.7	369.3
Non-Metallic Minerals	159.0	167.3	179.8	176.2	177.1	189.1	187.8
Food and Kindred Products	44.3	50.0	57.8	65.1	71.2	72.7	79.4
Lumber and Wood Products	52.6	55.4	56.5	54.5	53.4	54.5	54.2
Pulp, Paper and Allied Products	11.8	12.2	13.7	14.3	15.0	15.8	16.3
Chemicals	77.8	92.4	102.8	106.7	115.4	127.4	133.6
Petroleum and Coal Products	469.5	438.8	375.7	351.4	322.8	285.6	277.5
Stone, Clay, Glass and Concrete Problems	16.2	19.8	21.4	22.2	22.9	25.5	27.1
Primary Metals Products	34.3	33.9	43.5	55.5	62.5	70.6	75.0
Waste and Scrap	21.8	23.8	26.4	27.1	27.6	28.5	29.1
Other Commodities	53.8	57.7	67.3	77.2	86.6	100.7	111.9
TOTAL	1,914.9	2,062.6	2,152.8	2,152.0	2,240.5	2,298.4	2,379.8

Waterborne Commodity Flow Projections - Bad Energy
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Farm Products	158.1	218.3	280.8	314.7	326.7	317.8	389.5
Metallic Ores	115.3	139.6	153.1	170.9	191.3	216.3	234.7
Coal	211.8	251.5	312.5	396.7	475.7	548.6	578.3
Crude Petroleum	488.7	534.8	524.3	449.2	419.1	350.9	335.6
Non-Metallic Minerals	159.0	167.3	180.8	182.7	185.0	192.2	194.4
Food and Kindred Products	44.3	50.0	56.2	64.4	69.7	74.3	73.5
Lumber and Wood Products	52.6	55.4	56.5	54.5	53.4	54.5	54.2
Pulp, Paper and Allied Products	11.8	12.2	13.7	14.3	15.0	15.8	16.3
Chemicals	77.8	91.1	99.7	105.3	114.7	127.8	136.2
Petroleum and Coal Products	469.5	439.9	376.5	348.1	315.9	275.7	266.5
Stone, Clay, Glass and Concrete Problems	16.2	19.8	21.5	23.4	24.7	27.1	28.8
Primary Metals Products	34.3	33.9	43.5	48.6	52.9	57.5	60.2
Waste and Scrap	21.8	23.8	26.5	27.0	27.6	28.4	28.9
Other Commodities	53.8	57.7	67.2	78.0	90.1	105.8	117.3
TOTAL	1,914.9	2,095.4	2,212.9	2,277.5	2,362.0	2,392.8	2,514.3

Waterborne Commodity Flow Projections - Baseline
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Upper Mississippi	30.9	39.5	44.7	48.9	56.9	63.5	66.0
Lower Upper Mississippi	77.5	90.0	101.9	113.3	134.2	153.5	162.0
Lower Mississippi	123.6	138.2	155.5	157.5	185.2	210.3	222.3
Baton Rouge to Gulf	344.4	393.1	422.1	422.6	472.2	511.7	534.9
Illinois Waterway	60.5	67.6	75.2	78.7	89.4	98.9	103.5
Missouri River	6.7	7.3	7.4	7.3	7.4	7.7	7.8
Ohio River	172.5	179.5	212.2	229.1	262.6	292.5	307.5
Tennessee River	26.5	26.9	27.3	40.9	52.1	61.5	66.9
Arkansas River	9.4	9.7	10.0	11.3	12.8	14.0	14.4
Gulf Coast West	341.3	378.7	364.2	353.5	367.6	369.2	385.7
Gulf Coast East	108.7	113.1	125.7	134.7	143.6	151.5	152.1
Mobile River and Tributaries	43.7	47.5	53.5	80.5	95.6	109.8	119.0
South Atlantic Coast	69.8	69.4	67.9	67.5	67.5	67.7	69.6
Middle Atlantic Coast	436.8	439.4	425.1	420.6	430.8	427.7	438.0
North Atlantic Coast	87.4	82.4	78.8	78.2	75.6	69.2	68.9
Great Lakes/SLS/ New York State Waterways	189.9	244.3	271.1	294.7	327.5	362.4	385.7
Washington/Oregon Coast	68.4	77.5	115.1	116.0	122.8	120.4	121.2
Columbia-Snake Waterway	43.5	51.9	52.8	52.9	53.4	55.0	58.6
California Coast	138.3	135.3	137.7	138.1	140.4	140.7	143.6
Alaska	28.8	95.7	99.3	94.3	91.5	87.1	86.2
Hawaii and Pacific Territories	15.3	15.8	16.7	17.7	18.9	20.4	21.5
Caribbean	89.8	92.2	86.0	84.2	82.1	74.0	74.5
Eliminate Interregional Flows	(598.5)	(716.1)	(755.1)	(805.0)	(899.9)	(982.6)	(1,024.0)
TOTAL	1,914.9	2,078.5	2,195.1	2,237.6	2,390.2	2,486.4	2,585.6

Waterborne Commodity Flow Projections - High Use
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Upper Mississippi	30.9	39.5	44.6	49.7	57.4	66.0	68.7
Lower Upper Mississippi	77.5	90.2	101.8	115.1	135.7	158.5	167.3
Lower Mississippi	123.6	138.4	155.2	160.2	188.7	218.5	231.0
Baton Rouge to Gulf	344.3	394.7	423.2	427.8	479.6	525.0	548.7
Illinois Waterway	60.5	67.8	75.2	79.6	90.2	101.3	106.4
Missouri River	6.7	7.3	7.4	7.3	7.4	7.7	7.8
Ohio River	172.5	180.4	212.7	248.5	282.4	331.1	345.2
Tennessee River	26.5	27.1	27.9	44.3	58.1	74.1	79.5
Arkansas River	9.4	9.7	9.9	11.5	13.0	14.6	15.0
Gulf Coast West	341.3	379.2	365.0	355.1	370.1	372.7	389.0
Gulf Coast East	108.7	113.1	125.8	139.7	152.1	165.9	168.2
Mobile River and Tributaries	43.7	49.0	54.3	86.9	105.0	127.1	137.4
South Atlantic Coast	69.8	69.4	67.9	68.0	68.4	69.0	71.1
Middle Atlantic Coast	436.8	444.1	428.5	431.2	446.3	457.7	469.2
North Atlantic Coast	87.4	82.4	78.8	78.3	75.6	69.2	68.9
Great Lakes/SLS/ New York State Waterways	189.9	250.0	275.7	307.0	344.3	386.4	411.1
Washington/Oregon Coast	68.4	77.5	115.1	116.0	122.8	120.4	121.2
Columbia-Snake Waterway	43.5	51.9	52.8	52.9	53.4	55.0	58.6
California Coast	138.3	135.3	137.7	138.1	140.4	140.7	143.6
Alaska	28.8	95.7	99.3	94.3	91.5	87.1	86.2
Hawaii and Pacific Territories	15.3	15.8	16.7	17.7	18.9	20.4	21.5
Caribbean	89.8	92.2	86.0	84.1	82.1	74.0	74.5
Eliminate Interregional Flows	(598.5)	(717.1)	(755.0)	(816.6)	(916.0)	(1,019.0)	(1,062.6)
TOTAL	1,914.9	2,093.8	2,206.8	2,296.7	2,467.2	2,623.4	2,727.2

Waterborne Commodity Flow Projections - Low Use
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Upper Mississippi	30.9	39.6	44.3	47.3	53.0	57.1	58.8
Lower Upper Mississippi	77.5	90.5	101.7	110.4	126.8	140.7	147.7
Lower Mississippi	123.6	138.9	134.2	148.3	166.3	181.3	190.7
Baton Rouge to Gulf	344.3	401.6	425.0	412.2	447.2	472.1	492.1
Illinois Waterway	60.5	67.3	74.4	76.6	84.7	92.0	95.6
Missouri River	6.7	7.3	7.4	7.2	7.3	7.4	7.4
Ohio River	172.5	177.4	207.1	221.9	245.8	268.8	280.3
Tennessee River	23.9	22.4	24.9	38.6	49.4	57.2	61.7
Arkansas River	9.4	9.7	9.7	9.8	10.3	10.7	10.8
Gulf Coast West	341.3	391.0	370.5	351.5	359.5	360.4	376.9
Gulf Coast East	108.5	113.2	123.3	130.9	136.0	142.4	141.3
Mobile River and Tributaries	43.7	47.2	52.6	77.6	89.2	101.0	108.9
South Atlantic Coast	69.8	68.9	66.6	65.2	64.0	63.6	65.1
Middle Atlantic Coast	436.8	434.4	417.5	405.4	405.8	400.5	409.8
North Atlantic Coast	87.4	81.9	77.1	75.5	71.6	65.0	64.6
Great Lakes/SLS/ New York State Waterways	189.9	240.0	267.5	276.5	298.9	326.1	345.2
Washington/Oregon Coast	68.4	74.3	110.9	110.3	114.5	109.9	109.4
Columbia-Snake Waterway	43.5	51.8	52.5	52.5	52.8	54.4	57.9
California Coast	138.3	126.0	124.7	123.1	119.9	115.3	115.0
Alaska	28.8	95.9	99.6	94.5	91.6	87.3	86.4
Hawaii and Pacific Territories	15.3	15.8	16.6	17.5	18.5	19.8	20.9
Caribbean	89.8	80.2	69.4	67.9	59.2	50.1	49.4
Eliminate Interregional Flows	(595.9)	(714.5)	(745.6)	(768.8)	(831.9)	(884.8)	(916.2)
TOTAL	1,914.9	2,062.6	2,152.0	2,152.0	2,240.5	2,298.4	2,379.8

Waterborne Commodity Flow Projections - Bad Energy
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Upper Mississippi	30.9	40.1	48.1	55.2	58.2	60.1	67.9
Lower Upper Mississippi	77.5	91.5	109.2	125.0	135.5	143.7	163.3
Lower Mississippi	123.6	140.5	163.0	177.0	196.3	207.0	235.9
Baton Rouge to Gulf	344.3	405.5	446.6	461.0	484.3	486.7	543.8
Illinois Waterway	60.5	68.3	78.9	86.7	91.5	96.6	108.4
Missouri River	6.7	7.3	7.4	7.4	7.3	7.1	7.0
Ohio River	172.5	179.6	210.3	245.2	279.6	308.1	324.5
Tennessee River	26.5	26.9	27.3	41.5	53.6	62.3	67.3
Arkansas River	9.4	9.7	10.0	12.2	14.4	15.5	16.5
Gulf Coast West	341.3	389.3	374.9	361.5	361.7	354.7	362.2
Gulf Coast East	108.7	113.1	125.2	131.9	135.7	138.3	140.5
Mobile River and Tributaries	43.7	49.3	54.2	82.2	96.8	108.9	120.4
South Atlantic Coast	69.8	68.9	65.4	64.0	62.7	62.1	63.8
Middle Atlantic Coast	436.8	440.7	422.3	415.7	418.0	413.4	427.5
North Atlantic Coast	87.4	82.1	77.1	74.9	70.8	63.6	63.0
Great Lakes/SLS/ New York State Waterways	189.9	248.2	275.3	301.7	333.7	369.2	392.7
Washington/Oregon Coast	68.4	74.5	112.3	113.7	116.7	112.1	113.0
Columbia-Snake Waterway	43.5	51.0	56.1	58.9	57.5	56.3	54.6
California Coast	138.3	125.8	124.9	122.7	118.7	113.6	113.3
Alaska	20.8	95.9	99.6	104.7	101.4	96.5	95.4
Hawaii and Pacific Territories	15.3	15.8	16.6	17.5	18.7	20.0	21.1
Caribbean	89.8	92.4	84.3	79.8	76.4	67.9	68.0
Eliminate Double-Counting	(598.5)	(721.9)	(776.9)	(863.7)	(927.4)	(971.0)	(1,055.0)
TOTAL	1,914.9	2,095.4	2,212.9	2,277.5	2,362.0	2,392.8	2,514.3

Waterborne Commodity Flow Projections - Defense
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Farm Products	158.1	212.4	244.4	216.5	298.9	340.0	366.2
Metallic Ores	115.3	139.6	155.1	289.5	199.3	225.7	244.3
Coal	211.8	254.1	315.8	409.5	425.1	608.7	642.8
Crude Petroleum	488.7	534.5	536.5	515.4	477.4	424.8	423.6
Non-Metallic Minerals	159.8	168.1	180.4	153.2	194.8	208.4	209.8
Food and Kindred Products	44.3	49.5	57.1	48.2	74.1	84.7	92.4
Lumber and Wood Products	52.6	55.4	56.5	50.4	53.4	54.5	54.2
Pulp, Paper and Allied Products	11.8	12.2	13.7	14.5	15.0	15.8	16.3
Chemicals	77.8	91.5	102.6	129.3	118.2	131.8	139.2
Petroleum and Coal Products	470.5	440.0	384.8	473.3	342.0	306.4	299.2
Stone, Clay, Glass and Concrete Products	16.2	20.9	23.1	23.3	27.9	30.9	32.8
Primary Metals Products	34.3	33.9	43.5	46.5	52.0	56.1	58.4
Waste and Scrap	21.8	23.8	26.6	38.3	27.7	28.6	29.2
Other Commodities	53.8	57.7	67.5	91.3	91.1	107.1	118.8
TOTAL	1,914.9	2,093.8	2,206.8	2,499.6	2,467.2	2,623.4	2,727.2

Waterborne Commodity Flow Projections - High Coal Exports
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Farm Products	158.1	212.4	244.4	251.2	298.9	340.0	366.2
Metallic Ores	115.3	139.6	155.1	175.9	199.3	225.7	244.3
Coal	211.8	264.4	352.8	472.6	585.0	756.0	805.2
Crude Petroleum	488.7	534.5	536.5	479.1	477.4	424.8	423.6
Non-Metallic Minerals	159.0	168.1	180.5	187.1	194.8	205.4	209.8
Food and Kindred Products	44.3	49.5	57.1	67.2	74.1	84.7	92.4
Lumber and Wood Products	52.6	55.4	56.5	54.5	53.4	54.5	54.2
Pulp, Paper and Allied Products	11.8	12.2	13.7	14.3	15.0	15.8	16.3
Chemicals	77.8	91.5	102.6	107.7	118.2	131.8	139.2
Petroleum and Coal Products	469.5	440.0	384.8	366.2	342.0	306.4	299.2
Stone, Clay, Glass and Concrete Products	16.2	20.9	23.1	25.8	27.9	30.9	32.8
Primary Metals Products	34.3	33.9	43.5	48.2	52.0	56.1	58.4
Waste and Scrap	21.8	23.8	26.6	27.2	27.7	28.6	29.2
Other Commodities	53.8	57.7	67.5	78.7	91.1	107.1	118.8
TOTAL	1,914.9	2,104.0	2,244.7	2,355.5	2,557.0	2,770.8	2,889.6

Waterborne Commodity Flow Projections - Other Adjustments
(Millions of Tons)

	1977[1]	1980	1985	1990	1995	2000	2003
Farm Products	158.7	213.1	245.4	252.3	300.5	342.1	368.8
Metallic Ores	115.5	139.8	155.5	176.3	200.0	226.6	245.4
Coal	223.2	266.2	330.5	434.7	528.6	640.5	677.4
Crude Petroleum	488.7	534.5	536.6	479.1	477.5	424.9	423.7
Non-Metallic Minerals	161.1	170.2	182.7	191.0	200.3	215.4	217.6
Food and Kindred Products	44.4	49.7	57.3	67.5	74.4	85.1	92.9
Lumber and Wood Products	52.6	55.4	56.6	54.5	53.4	54.5	54.2
Pulp, Paper and Allied Products	11.8	12.2	13.7	14.3	15.1	15.9	16.4
Chemicals	78.7	92.5	103.9	109.3	120.3	134.6	142.4
Petroleum and Coal Products	472.7	442.3	387.2	368.7	344.7	309.2	302.2
Stone, Clay, Glass and Concrete Problems	16.4	21.1	23.4	26.1	28.2	31.2	33.2
Primary Metals Products	34.7	34.4	44.1	48.8	52.8	57.1	59.6
Waste and Scrap	21.8	23.9	26.6	27.2	27.8	28.7	29.3
Other Commodities	60.6	64.4	74.3	85.6	98.2	114.3	126.1
TOTAL	1,941.0	2,119.7	2,137.6	2,335.6	2,513.7	2,680.1	2,789.2

NOTE: (1) Base year data was adjusted for this forecast and the base year shown here differs from all other forecasts.

Waterborne Commodity Flow Projections - Defense
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Upper Mississippi	30.9	39.5	44.6	49.5	57.4	66.0	68.7
Lower Upper Mississippi	77.5	90.2	101.8	114.6	135.7	158.5	167.3
Lower Mississippi	123.6	138.4	155.2	163.7	188.7	218.5	231.0
Baton Rouge to Gulf	344.3	394.7	423.1	421.9	479.6	525.0	548.7
Illinois Waterway	60.5	67.8	75.2	98.8	90.2	101.3	106.4
Missouri River	6.7	7.3	7.4	7.3	7.4	7.7	7.8
Ohio River	172.5	180.4	212.7	277.1	282.4	331.1	345.2
Tennessee River	26.5	27.1	27.9	46.8	58.1	74.1	79.5
Arkansas River	9.4	9.7	9.9	12.7	13.0	14.6	15.0
Gulf Coast West	341.3	379.5	365.0	380.4	370.1	372.7	389.0
Gulf Coast East	108.7	113.1	125.8	146.1	152.1	165.9	168.2
Mobile River and Tributaries	43.7	49.0	54.3	86.2	105.0	127.1	137.4
South Atlantic Coast	69.8	69.4	67.9	77.0	68.4	69.0	71.1
Middle Atlantic Coast	436.8	444.1	428.5	463.8	446.3	457.7	469.2
North Atlantic Coast	87.4	82.4	78.8	87.6	75.6	69.2	68.9
Great Lakes/SLS/ New York State Waterways	189.9	250.0	275.7	426.9	344.3	386.4	411.1
Washington/Oregon Coast	68.4	77.5	115.1	129.8	122.8	120.4	121.2
Columbia-Snake Waterway	43.5	51.9	52.8	51.8	53.4	55.0	58.6
California Coast	138.3	135.3	137.7	174.1	140.4	140.7	143.6
Alaska	28.8	95.7	99.3	145.9	91.5	87.1	86.2
Hawaii and Pacific Territories	15.3	15.8	16.7	17.7	18.9	20.4	21.5
Caribbean	89.8	92.2	86.0	86.4	82.1	74.0	74.5
Eliminate Interregional Flows	(598.5)	(717.1)	(755.0)	(965.9)	(916.0)	(1,019.0)	(1,062.6)
TOTAL	1,914.9	2,093.8	2,206.8	2,499.6	2,467.2	2,623.4	2,727.2

Waterborne Commodity Flow Projections - High Coal Exports
(Millions of Tons)

	1977	1980	1985	1990	1995	2000	2003
Upper Mississippi	30.9	39.5	44.6	49.7	57.4	66.0	68.7
Lower Upper Mississippi	77.5	90.2	101.9	115.5	136.7	160.4	169.6
Lower Mississippi	123.6	138.6	155.9	163.0	195.7	231.9	246.6
Baton Rouge to Gulf	344.3	394.8	427.2	441.2	502.1	563.3	591.4
Illinois Waterway	60.5	67.8	75.2	79.6	90.2	101.3	106.4
Missouri River	6.7	7.3	7.4	7.3	7.4	7.7	7.8
Ohio River	172.5	180.5	213.3	251.0	288.8	343.4	359.6
Tennessee River	26.5	27.1	28.0	44.5	61.1	79.8	86.4
Arkansas River	9.4	9.7	10.0	11.7	13.4	15.3	15.8
Gulf Coast West	341.3	379.3	367.4	360.5	378.5	386.4	404.1
Gulf Coast East	108.7	113.1	125.9	139.8	152.3	166.2	168.5
Mobile River and Tributaries	43.7	49.4	60.5	101.1	126.5	162.9	177.6
South Atlantic Coast	69.8	69.4	67.9	68.0	68.4	69.0	71.1
Middle Atlantic Coast	436.8	454.0	453.5	452.5	471.6	499.3	514.7
North Atlantic Coast	87.4	82.4	78.8	78.2	75.6	69.2	68.9
Great Lakes/SLS/ New York State Waterways	189.9	250.0	275.7	307.0	344.3	386.4	411.1
Washington/Oregon Coast	68.4	77.5	115.1	116.9	130.0	131.4	132.9
Columbia-Snake Waterway	43.5	51.9	52.8	52.9	53.4	55.0	58.6
California Coast	138.3	135.3	138.2	142.2	146.5	149.8	153.4
Alaska	28.8	95.7	99.3	94.3	91.5	87.1	86.2
Hawaii and Pacific Territories	15.3	15.8	16.7	17.7	18.9	20.4	21.5
Caribbean	89.8	92.2	86.0	84.1	82.1	74.0	74.5
Eliminate Interregional Flows	(598.5)	(717.5)	(756.7)	(823.3)	(935.2)	(1,055.7)	(1,105.6)
TOTAL	1,914.9	2,104.0	2,244.7	2,355.5	2,557.0	2,770.8	2,889.6

Waterborne Commodity Flow Projections - Other Adjustments
(Millions of Tons)

	1977[1]	1980	1985	1990	1995	2000	2003
Upper Mississippi	31.1	39.7	44.9	50.0	57.8	66.6	69.4
Lower Upper Mississippi	78.5	91.3	103.3	117.0	138.1	161.6	170.7
Lower Mississippi	128.2	143.1	161.5	167.5	198.9	232.9	248.4
Baton Rouge to Gulf	354.5	405.8	434.8	440.4	494.8	544.8	578.4
Illinois Waterway	60.8	68.1	75.6	80.1	90.8	102.1	107.2
Missouri River	6.8	7.3	7.5	7.4	7.5	7.8	7.9
Ohio River	191.4	200.0	235.8	275.9	313.3	367.3	382.9
Tennessee River	25.5	26.1	27.1	44.4	59.0	75.7	81.4
Arkansas River	9.4	9.6	11.3	14.3	18.0	22.9	26.2
Gulf Coast West	342.2	380.5	366.2	356.6	371.9	374.9	391.5
Gulf Coast East	116.2	120.0	133.0	148.1	161.0	175.4	177.9
Mobile River and Tributaries	43.8	49.0	54.4	88.8	107.9	130.9	141.5
South Atlantic Coast	69.8	69.4	67.9	68.0	68.4	69.0	71.1
Middle Atlantic Coast	436.8	444.1	428.5	431.2	446.3	457.7	469.2
North Atlantic Coast	87.4	82.4	78.8	78.2	75.6	69.2	68.9
Great Lakes/SLS/ New York State Waterways	190.0	250.2	275.8	307.2	344.5	386.6	411.3
Washington/Oregon Coast	68.4	77.5	115.1	116.0	122.8	120.4	121.2
Columbia-Snake Waterway	43.5	51.9	52.8	54.7	56.5	59.3	63.7
California Coast	138.3	135.3	137.7	138.1	140.4	140.7	143.6
Alaska	28.8	95.7	99.3	94.3	91.5	87.1	86.2
Hawaii and Pacific Territories	15.3	15.8	16.7	17.7	18.9	20.4	21.5
Caribbean	89.8	92.2	86.0	84.1	82.1	74.0	74.5
Eliminate Interregional Flows	(615.4)	(734.5)	(776.5)	(844.3)	(952.2)	(1,066.4)	(1,117.3)
TOTAL	1,941.0	2,119.7	2,237.6	2,335.6	2,513.7	2,680.1	2,789.2

NOTE: (1) Base year data was adjusted for this forecast and the base year shown here differs from all other forecast. The Ohio and Gulf Coast East are most directly affected and the change affects all other regions which interact with these two regions.

IV - TRANSPORTATION CAPABILITY OF THE PRESENT SYSTEM AND POTENTIAL ACTIONS TO MAINTAIN OR IMPROVE CAPABILITY

PURPOSE OF SECTION

The purpose of this section of the report is to present and describe the major factors affecting transportation capability. The concept of capability is first defined. Then, in succeeding paragraphs the major factors affecting capability are described and the interaction among them analyzed qualitatively. The ultimate objective of the section is to provide an integrated understanding of capability as the concept was used in this phase of the NWS. This understanding will in turn facilitate interpretation by the reader of the Evaluation of the Present System presented in Section V and the formulation of strategies in the Element L Report entitled Evaluation of Alternative Future Strategies for Action.

Numerical evaluations of capability are presented in this section only to illustrate the points being made. The complete evaluation is in Section V.

The topics covered in this section are:

- Definition of Capability.
- Factors Affecting Capacity.
- Factors Affecting Line-Haul Cost.
- Factors Affecting Safety.
- Maintaining Capability.
- Actions To Increase Capacity.
- Actions To Improve Line-Haul Cost.
- Actions To Improve Safety.
- Summary.

DEFINITION OF CAPABILITY

For purposes of NWS, water transportation capability is defined as follows:

> WATER TRANSPORTATION CAPABILITY IS THE ABILITY OF THE PRESENT NAVIGATION SYSTEM TO HANDLE COMMERCIAL NAVIGATION SAFELY AND AT A LINE-HAUL COST CONSISTENT WITH THE HISTORICAL COST RELATIONSHIP AMONG THE TRANSPORTATION MODES.

This concept includes three specific components:

1. Annual throughput capacity (ability to handle commercial navigation)

2. Line-haul cost

3. Safety

The concept of capability relates directly to the concept of "needs" presented in Section II. No other aspects of navigation (e.g., environmental impacts) are included in the navigation capability concept since this is a study of the water transportation system and its ability to meet water transportation needs, not other needs. The treatment of other issues relating to navigation is introduced as appropriate.

The discussion of capability that follows builds from very basic concepts to more complex interrelationships. The purpose is to present the logic applied and the basic empirical findings utilized in developing an understanding of capability suitable for the NWS integration process. The discussion draws heavily on Element K1 (Engineering Analysis of Waterways Systems) and prior submissions of preliminary integration findings. The overall objective is to provide the reader with an understanding of how the navigation system was viewed during the integration process and lay the groundwork for interpreting the remainder of the K2 Report (Evaluation of the Present System) and for understanding the strategy formulation processes documented in the L report (Evaluation of Alternative Future Strategies for Action).

FACTORS AFFECTING CAPACITY

(a) Channel Dimensions

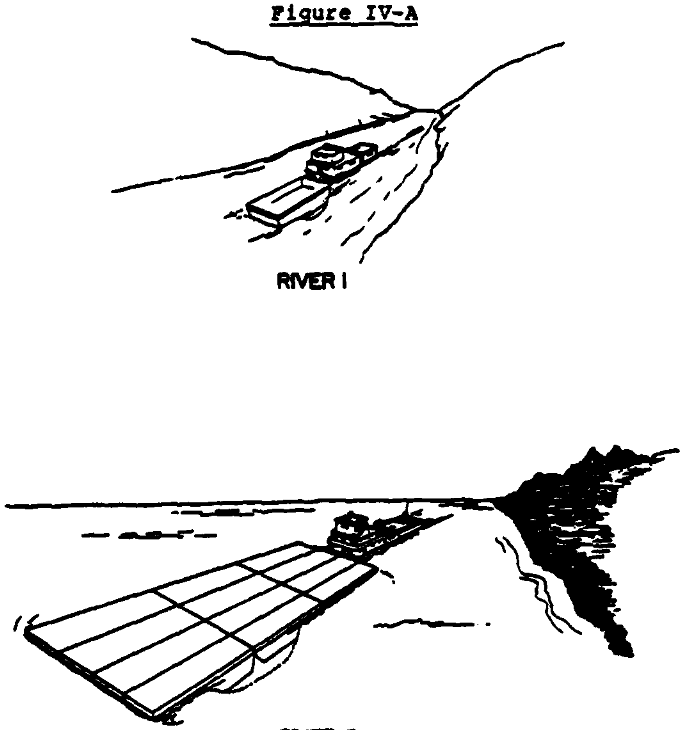
The first step in understanding navigation system capacity is to understand how channel conditions affect capacity. Every waterway has a variety of characteristics, but for open channels with no physical obstacles such as bends, locks, or bridges, two primary factors are important determinants of capacity:

- Channel depth.

- Channel width.

These two factors determine the "instantaneous carrying capacity" of a particular channel. The concept of carrying capacity is illustrated in Figure IV-A.

Figure IV-A



RIVER 1

RIVER 2

Figure IV-A illustrates that instantaneous (or carrying) capacity is three dimensional. Instantaneous capacity is determined first by channel depth. Greater depth allows deeper loading of barges and vessels. Channel width determines the number of barges that can be carried abreast and the maximum beam of self propelled vessels. Channel width and channel bends together limit tow and vessel sizes. The curvature of bends determines the maximum overall length of tows and vessels that can safely navigate a particular river or channel. The relationship between channel depth, tow size, and instantaneous capacity is shown in Table IV-1 for jumbo covered hopper barges operating on shallow draft river segments.

Table IV-1

Instantaneous Capacity for Selected Depths and Tow Sizes (Tons)

Depth of Loading	Number of Barges in Tow 4	6	15	25
7 feet	4,667	7,000	17,500	29,167
8 feet	5,333	8,000	20,000	33,333
9 feet	6,000	9,000	22,500	37,500
12 feet	8,000	12,000	30,000	50,000

SOURCE: NWS Working Papers.

As can be seen from Table IV-1, the differences in instantaneous capacity can vary widely across different types of segments, depending on both draft and tow size. A similar analysis can be applied to other types of barges and water transportation units such as tankers or Great Lakes ore carriers.

The complete concept of channel capacity must also include a time dimension. The unit of measure chosen for NWS is "annual throughput," that is, the amount of commerce that could be handled in a year. This is determined by the maximum safe speed, minimum safe interval between tows or vessels, and maximum tow or vessel size, particularly length.

(b) Locks and Other Sources of Delay

The simplest waterway is a straight line between two points with uniform depth and width. Any obstacle or restriction on traffic which causes tows or vessels to travel more slowly than the normal maximum safe speed or come to a complete standstill causes delays, which in turn reduces the throughput capacity of a segment. If the delays become severe enough to cause tows or vessels to wait for others, congestion occurs. This occurs when the actual inter-arrival time between tows or vessels at the delay point is less than the time required to pass the delay point.

Potential sources of delay include channel width restrictions (one-way traffic), horizontal clearances (bridges), vertical clearances (bridges), shore facilities, severe bends, and locks. The principal delay points for commercial navigation are locks because the time required to pass through a lock exceeds the time required to pass other obstacles.

In the case of a constraining point which imposes delays, the capacity of a waterway is the amount of time available for safe vessel or tow passage divided by the average service time of the constraining point given ladings, tow size, and percent loaded. Given certain channel dimensions, the capacity of a segment with constraining points such as locks is set by the capacity of these points.

The impact of a delay point such as a lock on the ability of a waterway to handle traffic is illustrated in Table IV-2.

Table IV-2

Comparison of Channel and Lock Capacity

	Estimated Tonnage Capacity
Lock and Dam 22(1)	29,000,000
Constricted Channel	185,000,000
Open Channel	369,000,000

NOTE: (1) Lock capacity under present conditions with no minor structural or non-structural actions being taken to increase capacity.

SOURCE: NWS Element K1, Engineering Analysis of Waterways Systems and NWS Working Papers.

As can be seen from Table IV-2, the channel capacity of the Upper Mississippi, even if it is in some way constricted such that the average speed is cut in half, far exceeds the capacity of the lock. Therefore, Lock and Dam 22 constrains the total capacity of the segment and is the controlling constraint with regard to other locks since most of the segment traffic passes through this facility.

The important conclusion of this discussion, drawn largely from prior work in NWS, is that locks are the primary capacity constraints. Other causes of delay do not constrain capacity nearly as much as do locks. Further, the delays from these other sources are insufficient to cause significant congestion except in isolated instances. It is also useful to understand that relatively few locks will constrain traffic and these are

readily identifiable. These then can become logical focal points for actions to alleviate capacity constraints.[1]

Accordingly, a great deal of emphasis has been placed on lock capacity for the integration analysis. Exhibit IV-1 presents lock traffic and capacity estimates for all commercially important locks in the system as of 1977. Appendix B presents a discussion of how the lock capacity analysis performed in Element K1 (Engineering Analysis of Waterways Systems) was used in all subsequent integration work. Appendix C presents the methodology for estimating lock capacity and the base-year data used in the lock capacity analysis for all commercially important locks in the system. It should be emphasized that, in order to complete the lock capacity evaluation and the evaluation of strategies it was necessary to develop lock specific forecasts of both traffic and capacity for all scenarios. This was not envisioned in the original NWS workplan.

Other sources of delay, on the other hand, are more widespread, more numerous, and more diverse. Most of them are unavoidable components of the system (e.g., fleeting areas and harbors). Some are privately owned and operated and difficult for public agencies to influence or change (e.g., terminals and loading piers), and some cannot be changed without adversely affecting other aspects of the system (e.g., bends which, when eliminated, would result in faster currents and reduced depths). Thus the primary focus of capacity analysis is necessarily on locks.

(c) Other Water Uses

One issue studied in depth in Element G (Analysis of Navigation Relationships to Other Water Uses) during the NWS was the relationship of navigation to other water uses. While the study was designed based on an assumption that interaction between navigation and other uses was significant, the conclusion arrived at was that other water uses were not significant.

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1 Actions are defined as discrete changes in activities or construction of facilities. In the case of locks actions are changes in lock operating rules or additions to physical capacity.

Other water uses interact most strongly with navigation when water is withdrawn from a waterway system as part of a multipurpose development scheme. Such uses are referred to as offstream uses. Irrigation is the only major off-stream use which does not return a high percentage of water to main channels and so far no conflicts have arisen. Future conflicts with irrigation may occur on those segments where navigation depends on releases from storage reservoirs to maintain channel depths, namely the Missouri River.

Instream uses, on the other hand, are generally compatible with commercial navigation and have low levels of interaction. These uses include flood control, hydroelectric power, recreation, and fish and wildlife. Conflicts with recreational boating can occur in busy harbors and at locks, although conflicts to date have been minor and are not projected to worsen significantly by the year 2000. Hydro-electric power is a highly complementary use except where power generation competes with locks for water or peak generation cycles create surges below reservoirs. To date, these conflicts have occurred at only a few sites (Alabama River and Cumberland River at Barkley Lock), have been minor where they have occurred, and are not expected to worsen significantly in the future.

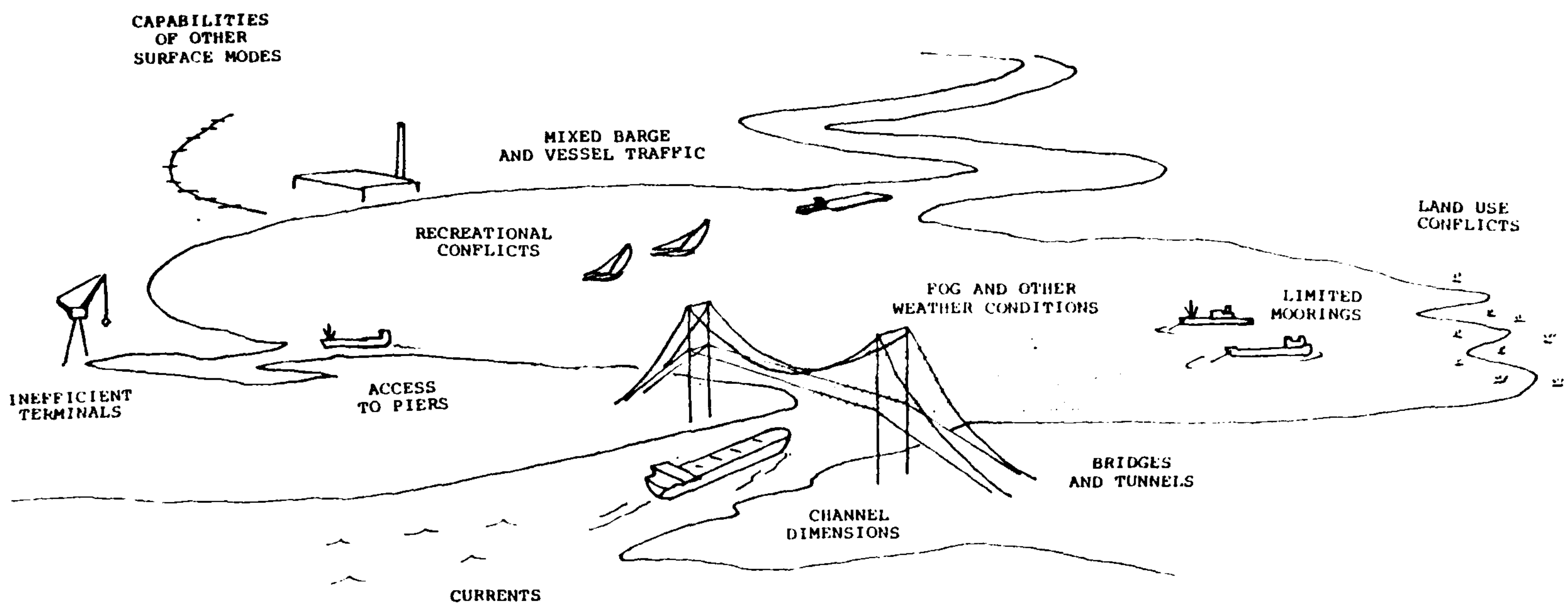
Other water uses (flood control, fish and wildlife, domestic and industrial consumption, and other recreation) were found to have no effect or to have low levels of interaction, often complementary and conflicting at the same time. Thus other water uses, initially believed to be important for navigation, were found to be generally unimportant.

(d) Ports

Ports, as the interface between water line-haul transportation and land side activities require a special discussion. Ports are centers of complex activities which interact in a variety of ways and are influenced by a wide variety of factors. These factors are illustrated in Figure IV-B.

Figure IV-B

PORT OVERVIEW



As can be seen in Figure IV-B, the number of factors that are potential constraints to port capability is quite large. These may be broken down into general categories of factors as follows: 1) factors limiting vessel capacity, 2) factors affecting vessel operations, 3) terminal capacity, and 4) other landside constraints. These are discussed in turn.

Vessel capacity is a potential constraint to port throughput capacity. If a port can accept only small vessels then the ultimate capacity is limited to the number of those vessels that can be processed. Constraints on vessels at ports are the same as in rivers, namely channel depths, channel width, and vertical and horizontal clearances. Also, the line-haul cost of vessels using a particular port are affected by the same factors influencing vessel capacity. In general, large vessels are cheaper to use and key factors such as depths can strongly influence this aspect of capability.

Factors affecting vessel operations are those factors which influence the movement of vessels into, out of, and within a port. Anything which impedes vessel movements or limits the availability of the port would be included in this class of constraint. Thus physical obstacles which restrict vessel size also often affect vessel operations since underway speeds typically are reduced while negotiating such hazards. Adequate mooring areas would also fall within this class of constraints. Seasonal factors which affect access to ports (fog, storms, high winds, unusual tides and ice) act on port capacity by restricting vessel operations and reducing the number of vessels which can be processed in a year. Port safety, which is one part of capability, is directly related to these factors. Vessel operations are modified to deal with these constraints primarily out of concern for safety. Theoretically, tradeoffs between port capacity and port safety could be made. However, safety usually dominates decisions about vessel operations since vessel operations are not normally the most important constraint to overall port operations.

Based on interviews conducted as part of Element D (Overview of the Transportation Industry) in NWS, and a

review of other sources, the conclusion was reached that terminals (the facilities which transfer cargo to and from deep draft vessels to and from the shore or directly to and from other transportation vehicles) and/or land for construction of new terminals are presently capacity constraints at ports. However, this is not true for all commodities and all ports. In general the United States has adequate aggregate terminal capacity for most commodities. These terminals may not all be advantageously situated or may even be uneconomic, but a judgment of terminals at this level was beyond the scope of NWS.

It became apparent in June of 1980 that export coal terminals which presently rely on rail receipts of coal are a major short term constraint to port throughput capacity for this one commodity. A detailed review of these constraints was not conducted since a decision was also made in June of 1980 that only activities normally undertaken by federal agencies traditionally involved in national water transportation programs would be included in strategies.

Finally, other landside factors can constrain port throughput capacity, safety, and costs. These factors include physical and institutional constraints. Poor service and limited capabilities by other surface modes may restrict throughput capacity and can certainly affect the costs of using various ports. Institutional factors include such items as the inability by some ports to secure favorable rates from railroads for movements into and out of their boundaries. The list could be expanded but it would be pointless to do so since detailed consideration of these factors in NWS strategies was ruled out, just as was consideration of terminals.

To summarize, a number of interviews with port officials and shippers were conducted during the course of NWS to explore their concerns and identify problems. A major conclusion of this research effort was that, assuming adequate channel maintenance, all the factors constraining or potentially constraining throughput capacity at ports are associated with terminals which are not subject to actions

taken by federal water resource agencies. A prime example of a lack of terminal capacity limiting waterborne shipments is the backlog of colliers waiting for loads at the Chesapeake Bay ports during 1980. The queue exists because of constraints on terminal capacity, not channels, moorings, locks, or anything relating to navigation *per se*.

FACTORS AFFECTING LINE-HAUL COST

(a) Channel Dimensions

Line-haul cost is the second component of capability. The variables which determine line-haul cost include lading, speed, tow size, delays, percent loaded, non-fuel and fuel costs.

The first four variables vary significantly among segments due to the physical characteristics of the segments and traffic densities. The last three variables are influenced by factors largely unrelated to the navigation system. They are determined by underlying commodity flows on specific segments or cost factors that do not vary widely across segments. The relationship of channel depth and tow sizes to line-haul ton mile costs are shown in more detail in Table IV-3. These estimates are provided for dry cargo carried in jumbo covered hopper barges.

Table IV-3

Cost Per Ton Mile for Selected Depths and Tow Sizes
(Cents/Ton Mile)

Depth of Loading	Number of Barges in Tow: 4	6	15	25
7 feet	1.3-1.1	1.1-0.9	0.8-0.6	0.5-0.3
8 feet	1.2-1.0	1.0-0.8	0.7-0.5	0.4-0.3
9 feet	1.1-0.9	0.9-0.7	0.6-0.4	0.4-0.2
10 feet	1.0-0.8	0.8-0.6	0.5-0.3	0.3-0.2

SOURCE: NWS Working Papers.

As can be seen from Table IV-3, there is a wide range of private ton-mile costs associated with different channel characteristics. This fact goes far to explain the low level of use for some rivers. Since line-haul cost is the primary advantage of water logistics systems, those rivers with characteristics which affect line-haul cost adversely and the carriers attempting to use them are placed at a strong competitive disadvantage and other modes may get the traffic.

(b) Locks and Other Sources of Delay

Delays at congestion points increase line-haul cost. Since delays due to congestion tend to increase geometrically with traffic, the costs associated with delays can grow rapidly and are beyond the control of the individual operators. For these reasons, delays at congestion points have been identified as a cost factor by carriers as an issue of concern. While delays impose significant additional line-haul costs, the costs imposed by shallower and narrower channels are normally much greater.

Line-haul cost estimates for domestic traffic for 1977 are shown in Exhibit IV-2. These estimates include estimated delays. The methodology and data used to estimate these line-haul costs are shown in Appendix D.

(c) Ports

Ports are by definition nodes of activity. The only line-haul cost incurred in ports is demurrage and local movements. Nevertheless, limitations on drafts and vessel sizes imposed by physical restrictions at ports do impact line haul cost. As noted earlier, larger tows and vessels operating with deeper drafts, have lower line-haul costs. This is especially important for overseas shipments of bulk commodities such as grain and coal where transportation costs are a major component of delivered prices. Thus actions to improve channel dimensions of ports can have a significant impact not only on the competitive status of individual ports, but can also affect the competitiveness of United States exports.

FACTORS AFFECTING SAFETY

(a) Background

Safe navigation occurs when accidents do not occur. The generally good safety record of the industry precludes a systematic rigorous analysis of safety, because there are relatively few accidents to analyze. Further, the methods of collecting and classifying accident data make analysis difficult. While a general understanding of the factors influencing safety is easy to obtain it is not possible to construct quantifiable causal relationships between factors affecting safety and some index of safety, which would allow prediction of future safety conditions. Accordingly, the approach to safety analysis was limited to identification of factors contributing to accidents, review of available records and studies, and identification of problem areas.

(b) Analysis of Factors Affecting Navigation Safety

The major types of casualties, the relative frequencies of their occurrence, and contributing causes are summarized in Table IV-4.

The data in Table IV-4 show that personnel faults are considered responsible for a high percentage of casualties by investigating authorities. These include failures of bridge operators, pilots, masters, and other crew members. For example, groundings are often attributed to personnel failures to find the proper channel.

Table IV-4

Summary of Marine Vessel
Casualties and Contributory Causes, 1978

Type of Casualty	Percent of Total Casualties	Primary Contributory Causes	Percent of Primary Causes
Grounding	24%	Fault of Other Vessel/Personnel	40%
Ramming	21%	Personnel Fault	28%
Material Failures	20%	Equipment Failure	14%
Collision	15%	Storms/Adverse Weather	5%
Foundering	8%	Channel Characteristics	3%
Fire/Explosion	5%		
Flooding	3%	Unseaworthy/ Improper Maintenance	2%
Capsizing	2%	Structural Failure	1%
Other	3%	Other	6%

SOURCE: United States Coast Guard data as cited in National Waterways Study, Defense and Emergency Requirements for Waterways.

Of the types of casualties listed in Table IV-4, 60% are "vessel control accidents." These include groundings, rammings and collisions. These types of accidents are in turn related to the physical marine environment and levels of traffic. A study of factors contributing to accidents on inland rivers found that the river segments where vessel control accidents frequently

occur had one or more of the following characteristics in common:

1. One or more bridges.

2. One or more locks.

3. A bend or intersection with another channel.

4. A narrow channel width.

Further, the study found that 35 distinct ten-mile reaches accounted for 35 percent of all vessel control accidents on inland rivers involving a barge or towboat. Similarly, a relatively small number of coastal ports and deep channels accounted for 44 percent of all vessel control accidents in 1977/1978. Sites identified from United States Coast Guard data for 1977 and 1978 and navigation charts as having major safety problems are listed in Exhibit IV-3.

As can be seen from the data in Exhibit IV-3, bridges are the most common characteristics cited in safety problem areas. Overall levels of congestion are deemed relatively more important in ports compared to inland rivers segments.

Thus, although personnel faults are most frequently blamed as the primary cause of vessel control accidents, a closer examination shows that the marine operating environment contributes strongly to accidents by decreasing safety margins. This in turn leads to the conclusion that obstructions to navigation such as bridges and locks (particularly bridges and locks which restrict traffic and cause delays) contribute to safety problems. Likewise, restrictive channel dimensions and unreliable channels (i.e., channels subject to frequent shoaling) impose a greater burden on operators, requiring more knowledge of channel conditions than is normally available.

A major conclusion of the review of available data and studies was that, while it is possible to infer that more accidents occur in unfavorable situations and in areas of

greater traffic, it is not possible to predict numerical values for future accidents and/or losses.

MAINTAINING CAPABILITY

There is an important distinction between maintaining or preserving the capability of navigation systems and taking actions to increase or improve capability. The discussion that follows deals with two specific types of actions relating to maintaining the capability of the present system.

(a) Channel Maintenance

Historically the Corps of Engineers has maintained a high degree of reliability for the channel dimensions of the present system primarily by means of dredging, particularly in areas of high use.[2] It is partly because of this good record that it was impossible to evaluate with a high degree of certainty the effects of varying levels of maintenance on the capability of the system.

In fact, dredging volumes have been reduced substantially in recent years due to environmental concerns. The effect of this reduction on capability up through the base year of the study (1977) has been minimal, as reported in the inventory of the navigation system compiled separately by the Corps as an early NWS activity. Therefore, it was assumed that the reported dredging volumes in the inventory represented a level of activity consistent with the baseline capability of the present system, while acknowledging several shortcomings in the data.

First, soundings are not taken frequently for some projects. Thus the true state of many of the navigation channels is not in fact known to Corps officials on even a monthly basis, much less a day to day basis. In the absence of soundings or grounding reports, the operating assumption is that channel dimensions are what they were

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2 Reliability is measured as the percentage of time that authorized channel dimensions are available.

last reported to be and the most recent report may be quite old.[3] Second, hydrological conditions on some rivers were unusually favorable during the period of time when the inventory data was recorded. When "normal" conditions resume, more channel dimension deficiencies may arise than the brief historical period of the inventory suggests. Third, it takes considerable time in some instances for rivers and other water regimes to reassert themselves as human intervention is reduced or eliminated. Thus, the full effect of reduced dredging in some segments may not have been revealed during the inventory period.

As previously mentioned, the dimensions of a waterway determine the maximum vessel size which can safely navigate on the waterway. Channel conditions, however, vary seasonally so that vessel sizes which can be safely navigated and drafts to which vessels can be loaded are also variable, being a function of the probability of occurrence and duration of hydrological conditions. Channel conditions also vary with the level of maintenance required to maintain authorized dimensions and the level of maintenance provided.

In order to prevent the reduction of channel dimensions and the resultant decrease in channel capability, the Army Corps of Engineers conducts an extensive channel maintenance program. There are three methods available for channel maintenance.

- dredging
- river training
- flow regulation

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3 Related to this is the lack of an adequate hydrological record for most rivers to provide a reliable systematic correlation between water flows and available depths. Thus, predicting both the need for and the effect of dredging is highly judgmental.

Maintenance dredging is performed to physically remove sediments which reduce channel dimensions, and it must be repeated periodically. River training and flow regulation techniques attempt to control water flow velocities preventing deposition which reduces channel dimensions. Maintenance dredging has the relative advantage of not requiring major initial investments but also does not provide a permanent solution. River training (construction of dikes and provision of revetments) and flow regulation (controlled release of water from the construction of basin reservoirs) may maintain channel dimensions but require a major initial investment and may not yield the desired result without supplemental dredging.

The determination of maintenance needs requires a great deal of experience on the waterway in question and detailed project level evaluation in order to provide authorized dimensions reliably at a minimum cost. This is due to the inability of available methods to reliably evaluate the effectiveness of the various maintenance techniques and in determining the level of maintenance effort required because of the complexity of the hydrological phenomena which define the need for maintenance.

While the effectiveness of maintenance activities can be judged at the extreme microlevel by Corps field personnel who devote years of their lives to understanding the processes of channels within their spheres of responsibility, there is no effective way to translate this level of management into a more global view of maintenance cause and effect due to a lack of methodology and uniform, systematically maintained data bases for all projects.

There are three basic types of waterways, grouped according to general hydrographic conditions, which determine their maintenance requirements: canalized waterways (with locks and dams), channelized waterways (free-flowing rivers), and coastal waterways comprising coastal port deep draft approach channels and lakes.

On canalized waterways, relatively stable navigation conditions are provided as a result of dam construction. Dredging requirements generally are small. Roughly 3,400 cubic yards per mile of canalized waterway nationally each

year is dredged, primarily in approaches to locks. Due to the stability of canalized waterways, dredging generally need only be repeated once every three to five years.

On channelized rivers, dredging, river training, and flow regulation can all be used to maintain channel dimensions. Due to the intensity of hydrological processes, dredging on these waterways is approximately 25,000 cubic yards per mile nationally each year.[4] The value might be much higher if the flow of the Mississippi River was not partially regulated and the Lower Mississippi River was not trained along much of its length. Dredging requirements on channelized waterways are highly seasonal and dredging may have to be undertaken annually.

Reduction of channel dimensions due to sedimentation on the Great Lakes and in coastal areas is a result of waves, coastal currents, and estuarial flow. The volume of dredging required in any given area is dependent upon the volume of sediment entering the estuary and circulation pattern of sediments within the estuary. Hence, alternatives to dredging are limited.

Two basic methods of dredging are currently employed: pre-maintenance dredging and dredging on an "as needed" basis. As the name implies, "as needed" dredging is performed whenever channel dimensions become close to, equal to, or less than authorized dimensions. Pre-maintenance dredging is performed by dredging to depths beyond those authorized in anticipation of sedimentation. While pre-maintenance dredging allows a degree of flexibility in scheduling dredging operations, and reduces dredging unit costs by increasing the quantity dredged in each operation, greater volumes must generally be dredged to be effective.

Several waterways in the United States were identified in Element K1 (Engineering Analysis of Waterways Systems) as having either dimensional deficiencies or an insufficient probability of maintaining authorized depth as a result of adverse hydrological conditions at low flow

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4 Element K1, Engineering Analysis of Waterways Systems

stage. The most important of these waterways in terms of potential for dimensional problems are: the Upper Mississippi River, the Middle and Lower Mississippi River, the Missouri River and the Apalachicola River.

From the Lower Middle through the Lower Mississippi River, authorized depth is 12 feet, but the Corps only attempts to maintain a 9 foot channel. The overall effect is that a 9 foot minimum depth is experienced much less than 5 percent of the time. It is anticipated that greater depths will be achieved (12 feet with a high degree of reliability) with the completion of the ongoing river training program without increasing (or possibly decreasing) the current level of maintenance dredging.

On the Missouri and the Apalachicola Chattahoochee/ Flint Waterways, the maintenance of authorized channel dimensions is somewhat unreliable due to significant hydrological changes induced by other than navigation users of water resources. In both waterways, channel dimensions are reduced when releases from multi-purpose basin storages are insufficient to maintain minimum design flow. On the Missouri River this condition generally exists for four winter months.

(b) Rehabilitation of Navigation Structures

Navigation structures (dams, locks, jetties, breakwaters, and dikes), like all physical objects, wear out with use and age. While normal maintenance will prolong the useful life of structures, there usually comes a time when major repairs are necessary to preserve the integrity and safety of the structure or to restore operating efficiency. An analogy can be drawn with automobiles. Normal automobile maintenance includes lubrication, and replacing of belts, tires, batteries, filters, and spark plugs. Extra-ordinary maintenance, such as engine replacement, is comparable to rehabilitation of navigation structures. In cases where an old, physically deteriorated structure cannot be repaired, replacement may be the most logical choice.

The difficulty arises in projecting future rehabilitation requirements. Historically the Corps has either let unused facilities deteriorate, replaced old facilities with new facilities, or not recorded rehabilitation as a separate activity. Thus there are little data on which to build predictions. Also, since rehabilitation actions are discreet major actions it would be necessary to predict not only which facilities would need rehabilitation but also at what time and at what cost. An alternative way of dealing with this problem was devised and is presented in the Element L report (Evaluation of Alternative Future Strategies for Action). The important point is to understand the distinction between rehabilitation (preserving present capability) and actions to change capability.

ACTIONS TO INCREASE CAPACITY

Based on the conclusion that locks are, and will remain, the primary controlling constraints on navigation capacity, it is useful to review the types of actions which can be taken to increase lock capacity. There are at least two ways of classifying actions to increase lock capacity. One way is the nature and quantity of resources used. Thus three categories were devised for NWS:

- Non-structural actions.
- Minor structural actions.
- Major structural actions.

These are discussed in turn.

(a) Non-Structural Actions

Non-structural actions are those changes in lock operating rules and policies that affect the way in which operators use locks. Three basic non-structural actions were considered in NWS. These were: 1) N up/N down

rules, 2) ready-to-serve policies, and 3) rules prohibiting the make-up and break-up of tows in lock chambers and approaches. All these serve to reduce the cycle times for various components of lockage times. None of these actions require either the use of significant physical resources or any change in a lock structure; hence they are called "non-structural."

"N up/N down" rules refer to lockage policies designed to take advantage of the characteristics of some locks. In general the Corps operates locks on a first come-first served basis, regardless of whether the tow or vessel requesting lockage is upbound or downbound. If a tow is moving in a direction that is contrary to the status of the chamber, an additional chambering operation is required before the tow to be locked can complete its lockage.

For example, if a downbound tow arrives at a lock and the preceding tow was also downbound, the lock chamber's lower mitre gates will be open and the water level in the chamber will be that of the lower pool. Before the new downbound tow can enter the chamber the lower gates must be closed, the water level raised, and the upper mitre gates opened. This is referred to as "chambering." A chambering operation with no tow or vessel in the chamber is referred to as a "turnback."

Due to characteristics which vary from site to site, the time required for a "turnback" lockage may be less than the time required for locking tows in an alternate direction (up, down, up, down, etc.). An N up/N down policy takes advantage of this time saving by locking through some number (N) of tows in one direction and then reversing the direction of traffic flow (up, up, up, down, down, down, etc.). This policy yields savings only if the time for a straight single lockage exceeds the total time for a turnback lockage. Further, it is used only when tows are queued on both sides of a lock.

"Ready-to-serve" policies and rules prohibiting tow make-up and break-up in lock chambers and approaches strive to reduce time lost in double and setover lockages. Double lockages occur when a tow has too many barges to fit in the chamber. Setover lockages occur when all of a tow will fit in the chamber but the tow requires reconfiguring. Reducing or eliminating the time lost while reconfiguration occurs reduces total lockage time. Also, these policies do not apply at locks where ships are the only type of traffic.

An example of a non-structural action that does not require a change in lock operating policy is the "self help" program installed voluntarily by operators at congested locks such as Locks and Dam 26. These programs can be quite effective in increasing lock capacity and have generally the same effect as rules prohibiting make-up and break-up in lock chambers and approaches.

One other "non-structural" action requires mention. At sites where recreational craft compete with commercial use of the lock, various rules can be applied to reduce or eliminate this conflict and make more time available to commercial users. These policies might include requiring recreational vessels to lock through with commercial users, limiting the number of "pure" recreational lockages, and outright prohibition of recreational lockages.

(b) Minor Structural Actions

Minor structural actions include a wide range of modifications to lock structures. The effectiveness of these actions tends to be very site specific. These actions include extensions to guidewalls, modifications to lock hydraulic systems, improved machinery and traveling kevils. All of these actions are designed to improve lockage times at low cost without changing chamber dimensions. Since resources would be consumed in implementing such actions, they are considered "structural" actions.

Some specific nonstructural actions at specific sites are discussed in the sensitivity analysis in Section V.

(c) Major Structural Actions

There are two major structural actions of universal applicability to increase lock capacity. The first action is to add an additional chamber at a site. The second action is to replace an existing chamber with a larger chamber. The appropriateness of either action depends upon the relation of chamber sizes to tow sizes and the condition of existing chambers, among other considerations.

In cases where lock availability is reduced by navigation seasons, annual lock throughput capacity can be increased by lengthening navigation seasons. These actions are most relevant to the Great Lakes/St. Lawrence Seaway locks, the Upper Mississippi, and the Columbia Snake Waterway.

Increasing channel depths will increase lock capacity and this increase may in some cases be possible without physically changing locks themselves. If greater depths resulted in greater ladings, more tonnage could be processed through locks using the same number of barges or vessels. For such an effect to be achieved without changing the locks, it would be required that all locks in a system be able to accommodate greater drafts than the channel. For small increases in drafts this is true for many locks and marginal gains in lock capacity can be obtained since many locks have more than adequate depths over sills. However, major changes in channel dimensions would in most cases also require major changes in locks. Channel deepening, as a means of obtaining major additional lock capacity, is therefore largely ineffective.

(d) Actions To Increase Lock Capacity Classified By Cost Responsibility

The second way of classifying actions to increase capacity is to examine who is involved in executing the action and who bears the costs. In general, non-structural actions result in somewhat higher outlays by operators, although this is probably more than offset by reduced delay costs in most instances. The two ways of classifying actions are shown in Table IV-5.

Table IV-5

Actions to Increase Lock Capacity

Actions	Acting Agency	Costs Borne By: Public Sector[1]	Costs Borne By: Private Sector
Non Structural			
1. N Up/N Down	Corps of Engineers		X
2. Restrictions on Double Lockages	Corps of Engineers		X
3. Ready to Serve	Corps of Engineers		X
4. Industry Self Help	Private Operators		X
5. Restrictions on Recreation Use	Corps of Engineers		X
Minor Structural			
1. All Actions	Corps of Engineers[2]	X	
Major Structural			
2. All Actions	Corps of Engineers[2]	X	

NOTES: (1) Under existing cost sharing policy.

(2) For Corps owned locks only.

ACTIONS TO IMPROVE LINE-HAUL COST

(a) Channel Dimensions

As noted earlier, line-haul cost is a decreasing function of tow/vessel size and drafts. Further, maximum tow/vessel sizes and drafts are determined by channel dimensions. Thus, two major potential actions are logically necessary to achieve significant changes in line-haul cost, namely deepening and widening of channels.

Channel deepening in open rivers is ultimately limited by the amount of water available. However, dredging and/or river training can increase controlling depths within the ultimate limit. Channel deepening in slack water systems on the other hand is, for practical purposes, unlimited by present technological factors. However, as noted earlier, deepening channels in slack water (canalized) systems requires substantial modification or replacement of existing locks. Channel deepening in harbors is mostly a matter of increased dredging once the initial deeper cut has been made.

Channel widening can also favorably affect line-haul cost, although there are fewer opportunities for this action within the context of the present navigation system. This is due to several factors. First, intermittent narrow reaches do not normally constrain tow/vessel size so much as they impose delays. Second, as with deepening, channel widths are ultimately limited by the amount of water available. Wider channels cause water to spread out and become more shallow when water flows are limited. Third, channel widening tends to be more costly due to the amount of shore line interests affected.

(b) Locks and Other Sources of Delay

Locks and other impediments to smooth uninterrupted movement increase transit times. Transportation resources are accordingly tied up longer and the entire process is more costly. Although the elimination or reduction of delay costs provides the primary justification for new lock facilities, it should be understood that these delays

become most costly as practical lock capacity is approached or exceeded. Thus the action of providing additional lock capacity has a favorable effect on line-haul cost although the immediate objective is increasing lock capacity.

ACTIONS TO IMPROVE SAFETY

The actions to improve safety considered for inclusion in NWS strategies are related to the situational factors identified as contributory causes of accidents. Structural actions at bridges range from fenders at identified hazardous bridges to removal and/or replacement of these bridges. Certain situational factors cannot be corrected, such as bends and junctions. Higher levels of traffic management (Vessel Traffic Services, known as VTS) are also included for areas of high levels of activity. Improved aids to navigation are also considered. Actions at locks range from fenders and moorings to lock replacement, although no locks would be replaced purely for safety reasons. All of these actions are oriented at reducing the likelihood of an accident (upgraded VTS) or reducing the potential damage from accidents when causal factors cannot be eliminated (e.g., fenders). Additional information concerning safety issues and causes of accidents can be found in the Element E/F Report (Review of National Defense, Emergency, and Safety Issues Affecting the Waterways).

SUMMARY

Certain major conclusions, based primarily on prior work in NWS, have been incorporated into this discussion of navigation capability and subsequent analyses. These are summarized below:

1. Capacity is determined by physical features of the navigation system and traffic characteristics.

2. The capacity of open channels exceeds present and projected traffic needs by wide margins with a few possible exceptions.

3. The capacity for slack water channels is limited primarily by locks.

4. Line-haul cost is most strongly influenced by channel dimensions.

5. Safety is most strongly influenced by human factors, channel width, channel depth, and physical obstacles.

6. Technological change will not affect capacity significantly but will affect line-haul cost.

7. Water supply for navigation will be adequate in the foreseeable future with possible shortages on a few rivers with low levels of traffic.

8. Other water uses have limited interactions with navigation and these are significant only on waterways with little commercial traffic.

Another important point to understand is that actions taken to achieve a change in one component (capacity, line-haul cost, or safety) of capability also affect the other components. Many of these overlapping effects are negligible and, accordingly, it is possible to classify actions by their primary effects.

Lock Traffic and Capacity in 1977
(millions of tons)

NWS Region	NWS Segment	River/ Waterway	Lock Name	Traffic	Capacity
Upper Mississippi	Upper Mississippi	Mississippi R., Minneapolis to mouth of Illinois R.	L&D 25	24.5	60.2
			L&D 24	24.4	60.2
			L&D 22	23.6	48.2
			L&D 21	23.0	60.8
			L&D 20	22.1	60.8
			L&D 19	21.7	49.3
			L&D 18	19.7	58.7
			L&D 17	19.1	58.2
			L&D 16	18.4	56.2
			L&D 15	16.8	57.3
			L&D 14	16.0	57.3
			L&D 13	14.1	51.2
			L&D 12	14.1	51.2
			L&D 11	13.1	50.3
			L&D 10	12.7	50.1
			L&D 9	12.0	50.6
			L&D 8	10.9	50.3
			L&D 7	10.7	50.1
			L&D 6	10.7	50.1
			L&D 5A	10.0	49.6
			L&D 5	10.0	49.6
			L&D 4	10.0	49.6
			L&D 3	9.5	48.7
			L&D 2	10.0	36.1
			L&D 1	2.5	19.7
			Lower St. Anthony	1.4	9.8
Lower Upper Mississippi	Lower Upper Mississippi	Mississippi R., Illinois R. to Missouri R.	L&D 26	56.1	73.3
	Middle Mississippi	Mississippi R., Missouri R. to Ohio R. (Chain of Rocks Canal)	L&D 27	64.2	146.2

Lock Traffic and Capacity in 1977
(millions of tons annually)

NWS Region	NWS Segment	River/ Waterway	Lock Name	Traffic	Capacity
Baton Rouge to Gulf	Ouachita, Black, Red	Black R.	Jonesville	0.8	26.7
		Ouachita R.	Columbia	0.5	26.7
			L&D 6	0.0[1]	17.8
			L&D 8	0.1	17.8
		Red R., mouth to Shreveport	L&D 1	0.0[2]	0.0[2]
	Old and Atchafalaya	Old R.	Old River	5.1	59.1
	Baton Rouge - Morgan City Bypass	Port Allen Route	Port Allen	14.2	35.2
			Bayou Sorrel	14.2	NC[3]
		Bayou Teche	Berwick	0.7	NC[3]
Illinois Waterway	Illinois Waterway	Illinois R.	LaGrange	30.5	46.6
			Peoria	28.8	44.4
			Starved Rock	22.1	42.7
			Marseilles	20.9	33.5
			Dresden Island	20.6	42.4
		Des Plaines R.	Brandon Road	18.6	42.5
		Chicago Sanitary and Ship Canal	Lockport	20.7	33.7
		Calumet R.	T.J. O'Brien	8.7	27.5
Ohio River[4]	Upper Ohio	Ohio River, confluence of Allegheny and Monongahela Rivers to Kanawha River	Emsworth	20.6	34.0
			Dashields	21.0	34.9
			Montgomery	18.8	34.9
			Cumberland	21.5	109.9
			Pike Island	24.5	101.0
			Hannibal	27.6	109.6
			Willow Island	28.1	107.0
			Belleville	28.9	104.7
			Racine	30.5	107.6
	Middle Ohio	Ohio River, Kanawha River to Kentucky River	Gallipolis	37.2	58.1
			Greenup	35.6	100.0
			Meldahl	31.2	96.6
			Markland	35.7	88.9
	Lower Ohio Three	Ohio River, Kentucky River to Green River	McAlpine	43.7	84.0
			Cannelton	44.6	107.4
			Newburgh	42.9	104.1

Lock Traffic and Capacity in 1977
(millions of tons annually)

NWS Region	NWS Segment	River/ Waterway	Lock Name	Traffic	Capacity
Ohio River	Lower Ohio Two	Ohio River, Green River to Tennessee River	Uniontown	49.3	114.0
			Smithland	55.6	177.4
	Lower Ohio One	Ohio River, Tennessee River to Mouth	L&D 52	62.5	NC[3]
			L&D 53	54.7	NC[3]
	Monongahela River	Monongahela River	L&D 2	18.4	51.0
			L&D 3	19.2	37.9
			L&D 4	14.8	37.7
			Maxwell	14.5	59.2
			L&D 7	6.2	17.8
			L&D 8	4.8	17.9
			Morgantown	1.1	25.6
			Hildebrand	0.8	25.5
			Opekiska	0.2	11.5
	Allegheny River	Allegheny R.	L&D 2	3.3	16.4
			L&D 3	2.8	16.4
			L&D 4	2.5	16.4
			L&D 5	1.9	16.4
			L&D 6	0.0[1]	16.4
			L&D 7	0.0	16.4
			L&D 8	0.0	16.4
			L&D 9	0.0	16.4
Ohio River	Kanawha River	Kanawha R.	Winfield	8.1	22.3
			Marmet	5.2	21.4
			London	1.4	20.1
	Kentucky River	Kentucky R.	L&D 1	0.5	6.4
			L&D 2	0.5	6.4
			L&D 3	0.5	6.4
			L&D 4	0.5	6.4
			L&D 5	0.0	6.4
			L&D 6	0.0	6.4
			L&D 7	0.0	6.4
			L&D 8	0.0	6.4
			L&D 9	0.0	6.4
			L&D 10	0.0	6.4
			L&D 11	0.0	6.4
			L&D 12	0.0	6.4
			L&D 13	0.0	6.4
			L&D 14	0.0	6.4
	Green River	Green R.	L&D 1	13.3	46.3
			L&D 2	11.5	46.3

Lock Traffic and Capacity in 1977
(millions of tons annually)

NWS Region	NWS Segment	River/ Waterway	Lock Name	Traffic	Capacity
Ohio River	Cumberland River	Cumberland R.	Barkley	8.8	38.7
			Cheatham	3.7	36.6
			Old Hickory	0.4	19.5
			Cordell Hull	0.0	19.5
Tennessee River	Upper Tennessee and Clinch	Tennessee R., head of navigation to junction with Tenn. Tom.	Wilson	7.0	36.5
			Wheeler	6.8	33.4
			Guntersville	4.0	32.0
			Nickajack	3.5	33.3
			Chickamauga	1.4	17.3
			Watts Bar	0.4	17.3
			Ft. Loudon	0.2	17.3
		Clinch R.	Melton Hill	0.0[1]	7.7
	Lower Tennessee	Tennessee R., junction with Tenn. Tom. to mouth	Kentucky	18.5	36.2
			Pickwick	8.3	33.7
Arkansas River	Arkansas, Verdigris, White and Black Rivers	Arkansas R.	Norrel	5.0	31.5
			L&D 2	5.0	31.8
			L&D 3	5.0	32.2
			L&D 4	4.8	33.1
			L&D 5	4.1	29.5
			Terry	4.1	31.2
			Murray	2.8	31.8
			Toad Suck	2.6	31.2
			L&D 9	2.6	31.8
			Dardanelle	2.6	31.5
			Ozark	2.5	31.8
			L&D 13	2.5	31.5
			Mayo	2.2	29.5
			Kerr	2.2	29.5
			Webbers Falls	2.1	26.0
		Verdigris R.	Chouteau	1.3	24.3
			Graham	1.2	24.3

Lock Traffic and Capacity in 1977
(millions of tons annually)

NWS Region	NWS Segment	River/ Waterway	Lock Name	Traffic	Capacity
Gulf Coast West	GIWW West One	Gulf Intra-coastal Water-way	Harvey	7.7	12.5
			Algiers	23.2	35.2
			Bayou Bouef	31.0	NC[2]
			Vermilion	43.0	NC[2]
			Calcasieu	43.8	NC[2]
Gulf Coast East	GIWW East One	Inner Harbor Navigation Canal	Inner Harbor	25.3[5]	32.0[5]
		Pearl River	L&D 1	0.1	17.8
Gulf Coast East	Apalachicola, Chattahoochee, Flint Rivers	Apalachicola River	Woodruff	0.4	15.3
		Chattahoochee River	Andrews	0.3	9.3
			George	0.2	10.9
Mobile River and Tributaries	Black Warrior, Mobile Harbor	Warrior R.	Bankhead	9.0	28.1
			Holt	11.7	28.4
			Oliver	12.0	23.8
			Warrior	12.0	26.6
		Tombigbee R.	Demopolis	11.1	35.3
			Coffeeville	11.6	45.7
	Alabama-Coosa	Alabama R.	Claiborne	0.7	35.3
			Millers Ferry	0.4	35.3
			Jones Bluff	0.0[1]	35.3
	Tennessee-Tombigbee Waterway	Tennessee[6] Tombigbee Waterway	Gainesville	0.0	0.0
			Aliceville	0.0	0.0
			Columbus	0.0	0.0
			Aberdeen	0.0	0.0
			A	0.0	0.0
			B	0.0	0.0
			C	0.0	0.0
			D	0.0	0.0
			E	0.0	0.0
			Bay Springs	0.0	0.0

Lock Traffic and Capacity in 1977
(millions of tons annually)

NWS Region	NWS Segment	River/ Waterway	Lock Name	Traffic	Capacity
Great Lakes St. Lawrence Seaway - New York State Waterways[7]	Lake Ontario and St. Lawrence Seaway	St. Lawrence River	St. Lambert	39.8	74.9[8]
			Cote Ste. Catherine	39.8	74.9[8]
			Lower Beauharnois	39.8	74.9[8]
			Upper Beauharnois	39.8	74.9[8]
			Snell	39.8	74.9[8]
			Eisenhower	39.8	74.9[8]
			Iroquois	39.8	74.9[8]
		Welland Canal	1	47.6	65.7[8]
			2	47.6	65.7[8]
			3	47.6	65.7[8]
			4	47.6	131.4[8]
			5	47.6	131.4[8]
			6	47.6	131.4[8]
			7	47.6	65.7[8]
			8	47.6	65.7[8]
	Lake Huron	St.Mary's R.	New Poe Mac Arthur	54.0[8]	115.7[8,9]
Columbia-Snake Waterway-Willamette River	Upper Columbia-Snake	Snake R.	Lower Granite	2.4	32.5
			Little Goose	2.4	32.5
			Lower Monumental	2.4	32.5
			Ice Harbor	2.4	32.5
		Columbia R.	McNary	4.7	32.5
			John Day	4.7	32.5
			The Dalles	4.7	32.5
			Bonneville	5.8	12.3

NOTES: NC = Not computed
(1) Less than 100,000 tons.
(2) No Red River Locks were open in 1977.
(3) Open Pass.
(4) Lock level traffic data for main stem Ohio River and Monongahela River locks is probably under-reported here. An error was discovered in the data base late in NWS and could not be corrected for all calculations. The subject is addressed in the sensitivity analysis in Section V of this report.
(5) Domestic traffic only.
(6) No Tennessee-Tombigbee Waterway locks were open in 1977.
(7) All data for Great Lakes locks is for United States traffic only.
(8) Adjusted to reflect capacity available for United States traffic only based on forecast relationships between U.S. and Canadian traffic. Total capacity for both U.S. and Canadian traffic combined is estimated for 1977 at 93.6 million tons for each St. Lawrence River Lock, 93.9 million tons for Locks 1, 2, 3, 7 and 8 on the Welland Canal, and 144.6 million tons for the Soo Locks. See Appendix C.
(9) All U.S. Locks at Sault Ste. Marie combined.

LINE-HAUL COSTS FOR DOMESTIC TRAFFIC IN 1977

NWS Region	NWS Segment	Mills Per Ton-Mile: Dry Bulk	Mills Per Ton-Mile: Iron & Steel Products	Mills Per Ton-Mile: Liquid Bulk	Mills Per Ton-Mile: Other
1. Upper Mississippi	1. Upper Mississippi, Minneapolis to Illinois R.	5	8	8	17
2. Lower Upper Mississippi	2. Lower Upper Mississippi, Illinois R. to Missouri R.	7	10	10	21
	3. Middle Mississippi, Missour R. to Ohio R.	5	8	8	16
3. Lower Mississippi	4. Lower Middle Mississippi, Ohio R. to White R.	3	5	5	12
	5. Upper Lower Mississippi, White R. to Old R.	3	5	5	12
	6. Lower Mississippi, Old River to Baton Rouge	3	5	5	12
4. Baton Rouge to Gulf	7. Mississippi R., Baton Rouge to New Orleans	3	5	5	12
	8. Mississippi R. New Orleans to Gulf	3	5	5	12

LINE-HAUL COSTS FOR DOMESTIC TRAFFIC IN 1977

NWS Region	NWS Segment	Mills Per Ton-Mile Dry Bulk	Iron & Steel Products	Liquid Bulk	Other
4. Baton Rouge to Gulf (Cont'd)	25. Ouachita, Black and Red Rivers	9	10	12	19
	26. Old and Atchafalaya Rivers	11	11	12	19
	27. GIWW Port Allen Route	8	9	10	15
5. Illinois Waterway	9. Illinois Waterway	4	8	8	17
6. Missouri River	10. Missouri River	11	13	23	17
7. Ohio River	11. Upper Ohio, Confluence of Allegheny and Monongahela to Kanawha R.	5	7	13	15
	12. Middle Ohio, Kanawha R. to Kentucky R.	4	5	8	15
	13. Lower Ohio Three, Kentucky R. to Green R.	4	4	7	15
	14. Lower Ohio Two, Green R. to Tennessee R.	5	5	7	15
	15. Lower Ohio One, Tennessee R. to Mouth	6	6	8	15
	16. Monongahela R.	9	9	16	23

LINE-HAUL COSTS FOR DOMESTIC TRAFFIC IN 1977

NWS Region	NWS Segment	Mills Per Ton-Mile Dry Bulk	Iron & Steel Products	Liquid Bulk	Other
7. Ohio River	17. Allegheny R.	11	10	20	22
	18. Kanawha R.	14	20	45	75
	19. Kentucky R.	11	9	17	24
	20. Green R.	8	9	8	34
	21. Cumberland R.	5	9	14	19
8. Tennessee River	22. Upper Tennessee and Clinch Rivers, Head of Navigation to Junction with Tennessee Tombigbee Waterway	5	5	13	18
	23. Lower Tennessee, Junction with Tennessee Tombigbee to Mouth	6	6	11	18
9. Arkansas River	24. Arkansas, Verdigris, White and Black Rivers	8	12	15	19
10. Gulf Coast West	28. GIWW West One, New Orleans to Calcasieu R.	9	10	10	23
	29. GIWW West Two, Calcasieu R., to Corpus Christi	8	9	9	21

LINE-HAUL COSTS FOR DOMESTIC TRAFFIC IN 1977

NWS Region	NWS Segment	Mills Per Ton-Mile: Dry Bulk	Mills Per Ton-Mile: Iron & Steel Products	Mills Per Ton-Mile: Liquid Bulk	Mills Per Ton-Mile: Other
10. Gulf Coast West	30. GIWW West Three, Corpus Christi to Brownsville	8	9	9	20
	34. Houston Ship Channel	8	9	9	20
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile	12	12	15	25
	32. Mobile to St. Marks, Fla.	11	12	14	16
	33. Florida Gulf Coast	3	6	2	3
	38. Apalachicola, Chattahoochee, and Flint Rivers	16	16	59	16
12. Mobile River and Tributaries	35. Black Warrior - Mobile Harbor	6	9	14	11
	36. Alabama and Coosa Rivers	9	9	13	16
	37. Tennessee-Tombigbee[1] Waterway				
13. South Atlantic Coast	39. Florida-Georgia Coast	3	6	2	3
	40. Carolinas Coast	3	6	2	3

LINE-HAUL COSTS FOR DOMESTIC TRAFFIC IN 1977

NWS Region	NWS Segment	Mills Per Ton-Mile: Dry Bulk	Mills Per Ton-Mile: Iron & Steel Products	Mills Per Ton-Mile: Liquid Bulk	Mills Per Ton-Mile: Other
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	3	6	2	3
	42. New Jersey -- New York Coast	3	6	2	3
15. North Atlantic Coast	44. Upper Atlantic, New York-Connecticut Boundary to St. Croix R., Maine	3	6	2	3
16. Great Lakes, St. Lawrence Seaway	43. New York State Waterways	19	19	21	19
	45. Lake Ontario and St. Lawrence Seaway	3	3	4	4
	46. Lake Erie	2	3	4	4
	47. Lake Huron	3	6	7	6
	48. Lake Michigan	2	3	4	4
	49. Lake Superior	2	4	4	4
17. Washington-Oregon Coast	50. Puget Sound	3	6	2	3
	53. Oregon-Washington Coast	3	6	2	3
18. Columbia-Snake Waterway	51. Upper Columbia-Snake Waterway	6	6	10	12
	52. Lower Columbia-Snake Waterway	6	6	10	12

LINE-HAUL COSTS FOR DOMESTIC TRAFFIC IN 1977

NWS Region	NWS Segment	Mills Per Ton-Mile			
		Dry Bulk	Iron & Steel Products	Liquid Bulk	Other
19. California Coast	54. Northern California	3	6	2	3
	55. San Francisco Bay	3	6	2	3
	56. Central-South California	3	6	1	3
20. Alaska	57. Southeast Alaska	3	6	1	3
	58. South Central Alaska	3	6	2	3
	59. West and North Coasts of Alaska	3	6	2	3
21. Hawaii and Pacific Territories	60. Western Pacific	3	6	2	3
22. Caribbean	61. Caribbean	2	5	2	3

NOTE: (1) Not in operation in 1977.

Sites With Major Safety Problems

Region	Segments	River-Mile/ Harbor	Bridges	Locks[1/]	Channel Configurations[2/]	Congested Traffic Areas
Upper Mississippi	Upper Mississippi	274		X		
		310	X			
		360-365	X			
		384	X			
		403-405	X			
		535	X			
		578-583	X			
		697-700	X			
		723-726	X			
Lower Upper Mississippi	Middle Mississippi	44	X	X		
		172-184	X			
Lower Mississippi	Lower Middle Mississippi;	735-755	X			
	Upper Lower Mississippi	361-365	X			
		428-445	X		X	
		531	X		X	
Baton Rouge to Gulf	Baton Rouge to New Orleans	165-175			X	
		210-225			X	
		225-235	X			
		109-235				X
	New Orleans to Gulf	75-85			X	
		85-109	X			
		0-109				X
	Old and Atchafalaya Rivers	5	X			
		30	X			
		41	X			
	Baton Rouge to Morgan City	0-3	X			
		0-64				X
Illinois Waterway	Illinois Waterway	150-155	X			
		160-165	X			
		239-240	X			
		244-247				X
		270-272	X			
		286-289	X			
		290-293	X			

Sites With Major Safety Problems

Region	Segments	River-Mile/ Harbor	Bridges	Locks[1]	Channel Configurations[2]	Congested Traffic Areas
Ohio River	Upper Ohio	0-15		x		
		32		x		
		53-54		x		
		0-54				x
		95		x		
		184-185		x		
		254-270[3]				x
	Middle Ohio	279		x		
		304-328				x
		340-350		x		
		460-485	x			
		531-532		x		
	Lower-Ohio-Three	597-607	x			x
		774-785		x		x
	Lower Ohio-One;	932-943			x	
	Monongahela;	0-11				x
	Green	8-10	x			
		71	x			
		80	x			
	Cumberland	126	x			
		185	x			
		189-193	x			
Tennessee River	Upper Tennessee	301-306				x
		414	x			
		462-471				x
	Lower Tennessee	66	x			
Gulf Coast West	New Orleans to Calcasieu River	0-7[4]	x			
		0-6[5]	x			
		13	x			
		35	x			
		49-50	x			
		55-60	x			
		85-241				x
		113	x			
		134	x			
		231	x			
		1[6]	x			
	Calcasieu to Corpus Christi	244	x			
		276-289				x
		353	x			
		356-358	x			
		393-405	x	x		
		418	x			

Sites With Major Safety Problems

Region	Segments	River-Mile/ Harbor	Bridges	Locks[1]/	Channel Configurations[2]/	Congested Traffic Areas
		440-442	X			
		533	X			
		36[7]/	X			
		Freeport	X	X		
	Houston Ship Channel	0-49			X	X
Gulf Coast East	New Orlean to Mobile Bay	6-8	X			X
		7-10[8]/	X			X
		Mississippi Sound			X	
		Pascagoula			X	
	Mobile Bay to St. Marks, Fla	Mobile				X
Mobile River and Tributaries	Black Warrior - Mobile Harbor	13	X			
		165	X			
		173	X			
		202	X			
		217			X	
		219	X			
		265	X			
		267	X			
		385			X	
		413	X			
		416	X			
		Locust Fork			X	
		Mobile	X			
South Atlantic Coast	Florida/Georgia Coast	7				X
		26-27	X			
		Savannah				X
Middle Atlantic Coast	Chesapeake and Delaware Bay	2-3	X			
		5	X			
		0-5				X
		0-3[9]/				X
		Baltimore				X
		Palmyra	X			
	New Jersey-New York Coast	Newark	X			
North Atlantic Coast	North Atlantic Coast	New Haven	X			
		Boston	X			
		Portland	X			

Sites With Major Safety Problems

Region	Segments	River-Mile/ Harbor	Bridges	Locks1/	Channel Configurations2/	Congested Traffic Areas
Great Lakes/ St. Lawrence Seaway	Lake Ontario and Seaway	Massena				X
		Johnstown			X	
	Lake Erie	Buffalo	X			
		Cleveland	X			
		Toledo	X			
	Lake Huron	Rouge R.	X			
		St. Mary's R.				X
	Lake Michigan	Calumet R.	X			
Wasington/Organ Coast	Puget Sound	Seattle	X			X
		Tacoma	X			
Columbia-Snake Waterway	Upper Columbia Snake W.	146		X		
	Lower Columbia-Snake W.	106	X			
		0-145				X
California Coast	San Francisco Bay Area;	San Franscisco	X			X
	Centra/South California	LA/Long Beach				X
Alaska	Southeast Alaska					X
Hawaii	Hawaii	Honolulu	X			

1/ Includes other waterway structures as well
2/ Includes bends and narrow channels; relative to traffic characteristics.
3/ Includes the Kanawha River as well
4/ Algiers route
5/ Harvey Canal
6/ Barataria Waterway.
7/ Calcasieu River
8/ Inner Harbor Navigation Canal
9/ Eastern Branch of Elizabeth River

V - EVALUATION OF THE PRESENT NAVIGATION SYSTEM

Is the present navigation system capable of accomodating current and projected waterborne commodity flows safely and at a linehaul cost consistent with the historical cost relationships among transportation modes? No simple answer is possible, given the myriad of regions and shippers served. In fact, as will be seen, the ability of the present system, barge and towing operators, and vessel operators to serve waterways-oriented industries varies substantially by region and scenario over the next quarter-century.

This section presents findings regarding the capability of the present waterways system to accommodate current and projected waterborne commodity flows safely and at a linehaul cost consistent with the historical cost relationships of transportation modes. The present system is evaluated under four scenarios and three sensitivity analyses.

The section is divided into the following major side headings:

- Present System Description.
- National Evaluation.
- Industry Evaluation.
- Regional Evaluation.
- Obsolete Locks.
- Summary.

After defining the present system, the overall capabilities of the system are evaluated with regard to lock capacity and linehaul costs.[1]

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1 Safety considerations are difficult to generalize in any meaningful way at the national level.

The evaluation of the system with regard to the major waterway industries is also discussed. This discussion focuses on traffic accommodated, waterborne share of total commodity supply, and linehaul costs.

Finally, the evaluation of the system with regard to selected regions is discussed. The discussion includes lock capacity, linehaul costs, and safety.

The findings from the sensitivity analyses of projected use (namely a defense forecast; high coal exports forecast; and miscellaneous forecasts for the Columbia-Snake Waterway, Arkansas River, Ohio River, and the Inner Harbor Navigation Canal) are included in the text as appropriate. The sensitivity analysis of the impact of minor structural actions on lock capacity is discussed briefly when the overall findings regarding lock capacity are discussed. A more complete treatment of this sensitivity analysis is presented in Appendix E of this report.

PRESENT SYSTEM DESCRIPTION

The current or baseline United States waterways system used in the National Waterways Study includes all navigable and/or maintained rivers, canals, ports and waterways as of December, 1978. Exhibit I-1 contains a description of all waterways defined as being part of the baseline system.

In addition, the present system has been defined to include the completion of the Tennessee-Tombigbee Waterway; completion of the Red River (Shreveport to Mississippi); the completion of the 12 foot deepening project on the Lower Mississippi (Cairo to Baton Rouge); a single 1,200' by 110' chamber at Lock and Dam 26 on the Mississippi and Vermillion Lock on the Gulf Intracoastal Waterway West; two lock chamber replacements on the Ouachita River; and the second chamber project at the Pickwick Lock on the Lower Tennessee River.

Before discussing the findings, the principal assump-

tions of this analysis should be quickly reviewed:

1. The lock capacity, linehaul, and safety analyses assume that current levels of federally-sponsored activity for operations, maintenance, and rehabilitation continue through the year 2003.[2]

2. Barge and towing companies, vessel operators, marine terminal operators, and shippers will continue to attract sufficient investment capital through profitable service to meet projected equipment and facility requirements.

NATIONAL EVALUATION

This evaluation of the present systems focuses on these measures:

1. Projected usage not accommodated by the present system due to lock capacity constraints.

2. Projected usage for all energy products (coal, crude petroleum, and petroleum products) not accommodated due to lock capacity constraints.

3. Average costs of domestic linehaul operations for domestic inland, Great Lakes, and coastal shipments.

As described in Section III, four alternative scenarios of projected use were prepared for NWS. The findings with regard to each forecast and the sensitivity analyses are summarized below.

(a) Baseline Scenario

Table V-1 presents the values of key national measures for the overall system from 1977 to 2003. The

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2 This assumption is relaxed in the analysis of strategies contained in the Element L Report (Evaluation of Alternative Future Strategies for Action).

Table V-1

National Evaluation Report
Scenario: Baseline

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		976.4	1,114.5	1,162.6	1,229.2	1,321.6	1,401.2	1,452.3
Foreign		938.5	964.0	1,032.4	1,008.4	1,068.5	1,085.2	1,133.3
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.5	98.4	97.8
Foreign		100.0	100.0	100.0	100.0	100.0	99.8	99.6
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.8	99.1	98.7
Foreign		100.0	100.0	100.0	100.0	100.0	99.9	99.8
Domestic Energy Traffic vs. Consumption of Energy Products	percent	40.5	42.7	40.2	36.2	34.6	31.7	30.2
Average Linehaul Costs	$/tonmile							
National		0.0059	0.0057	0.0062	0.0065	0.0069	0.0076	0.0079
Inland		0.0083	0.0085	0.0091	0.0092	0.0096	0.0103	0.0108
Great Lakes		0.0026	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030
Coastal		0.0018	0.0017	0.0018	0.0019	0.0020	0.0021	0.0022

measures include both estimates of traffic accommodation and line-haul costs.

1. Traffic Accommodation. The Baseline Scenario projects domestic waterborne traffic to increase at the annual compound growth rate of 1.5 percent over the 1977 to 2003 period, while foreign commerce increases at the slower rate of .7 percent per year. A primary reason for the much slower growth in import/export tonnage is declining petroleum imports as conservation and fuel substitution act to reduce the dependence of the United States on foreign oil supplies. A comparison of total traffic relative to projected usage reveals a short-term problem with domestic waterborne movements in 1985 (before the new 1,200' chamber at Dam 26 on the Mississippi River is brought on stream in 1990), and longer-term shortfalls in 1995 and beyond.

A comment is in order about the level of precision of the estimates shown in Table IV-1. The carrying of the percent of tons handled to the nearest tenth of a percent may convey an impression of accuracy than at first glance may seem spurious. This calculation was carried to this level for two reasons. First, if the results were shown at whole percentages, some results would be falsely presented. Specifically, the table would convey the false impression that all foreign traffic could be accommodated. Second, a whole percent of domestic traffic in 2003 would correspond to 15 million tons, a number much larger than the actual shortfall at many locks. Thus, the presentation in Table V-I corresponds more closely to the actual analysis.

The national evaluation report for the baseline scenario also indicates that lock constraints under present system configurations restrict, albeit only slightly, energy traffic on the waterways. In addition, energy traffic as a percent of domestic energy consumption steadily declines during the forecast period. Increasing dependence on coal and nuclear power, declining petroleum consumption, utility site locations favoring rail delivery of coal, and conversions of water-served utilities to other fuels and modes all contribute to the over ten percentage point decline in energy movements via water during the forecast period.

Figure V-A shows the constraining locks hindering movement of both foreign and domestic waterborne commerce

Figure V-A

NWS Constraining Locks:(1)
Baseline Scenario

NOTES:

(1) Capacity is reached or exceeded by projected usage in 2003.

(2) Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

(3) New 1,200' by 100' chamber is completed in 1990. The existing 110' x 600' and 110' x 360' constrains until replaced by the authorized single 110' x 1,200' chamber. The new chamber, in turn, becomes constraining in 1995.

(4) Locks 1, 2, 3, 7 and 8 only.

(5) Much of the traffic which is constrained at Demopolis is traffic which would use the Tennessee-Tombigbee Waterway. Since as an alternative routing is available to this traffic, it may not actually be diverted from the system altogether. However, it is worth noting that the alternative routing also uses three "problem" locks: Locks and Dam 52 on the Ohio, Lock and Dam 53 on the Ohio, and Inner Harbor Lock on the Gulf Intracoastal Waterway East.

(6) Constraining only if additional capacity is provided for the primary (controlling) locks.

in the forecast period.[3] By the year 2000, two additional (besides L&D 26) inland locks -- the LaGrange facility on the Illinois River and Gallipolis lock on the Ohio -- limit system traffic to near 98 percent of projected use. Foreign commerce is limited by St. Lawrence Seaway lock constraints (Welland 1, 2, 3, 7 and 8) in the year 2000 and beyond under the baseline scenario. By the year 2003, [illegible]tional inland locks -- the Peoria and Marseilles Locks on the Illinois River, L&D 22 on the Upper Mississippi River, and Demopolis on the Warrior River -- are constraining, and restrict waterborne commerce. (A complete list of locks included in the study, with river and NWS reporting segment definitions, can be found in Exhibit IV-1.)

Figure V-A shows locks where capacity falls short of projected usage. But, there is a larger number of locks where increased traffic congestion may merit replacement (using benefit-cost analysis from project level studies) in advance of a physical shortfall in capacity.

Table V-2 lists locks where increased traffic congestion and delays can be expected. As can be seen, some of these locks have comparable traffic levels and identical chamber dimensions to some of the constraining locks. For example, L&D 24 and L&D 25 on the Upper Mississippi are projected to have somewhat higher traffic levels than L&D 22 in the year 2003, but the unusually long chambering times at L&D 22 result in a lower level of capacity at this lock than the otherwise virtually identical chambers downstream.[4]

2. Linehaul Costs. Real private waterway costs for domestic linehaul operations increase at the annual rate of 1.1 percent per year for all shipments, 1.0 percent for internal shipments (rivers and Gulf Intracoastal Waterway), 0.6 percent for Great Lakes and St. Lawrence Seaway shipments, and 0.8 percent per year for coastal operations (see Table V-1). These costs are in constant 1977 dollars.

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3 Constraining locks are those locks where physical capability falls short of projected use by 2003 or earlier.

4 The capacity of L&D 22 is "sensitive" to the use of minor structural actions and is discussed later in this section.

Table V-2

Other Locks With Increased Congestion: Baseline Scenario[1]

NWS Region	Lock
Lower Upper Mississippi	L&D 27
Upper Mississippi	L&D 16, 17, 18, 19, 20, 21, 24 and 25
Illinois	Starved Rock Lockport
Ohio	Uniontown Newburgh McAlpine Dashields Emsworth
Tennessee	Kentucky
GIWW West	Harvey Algiers
GIWW East	Inner Harbor
Tombigbee-Alabama-Black Warrior	Warrior Oliver
Great Lakes/ St. Lawrence Seaway	St. Mary's River Locks
Columbia-Snake Waterway	Bonneville

NOTE: (1) Based on at least 60 minutes of average delay per tow or vessel. The same criterion is applied to all other scenarios and sensitivities.

The methodology and data used in calculating these linehaul costs are discussed in Appendix D. Briefly, these costs reflect real increases in energy prices, the fuel tax on marine diesel fuel for inland traffic (P.L. 95-502 specifies that the tax will rise to 10¢ a gallon by 1985), some savings from improved fuel consumption, increases in lock delays, and changes in operating conditions caused by "changes" in the mix of traffic.[5]

The faster rate of increase in linehaul costs for internal traffic reflects the fact that increasingly significant delays are encountered at various locks in this system.

The rate of increase in linehaul costs is slowest for coastal traffic, reflecting the fact that only fuel costs force an increase in real costs here.

(b) High Use Scenario

Table V-3 presents the values of national measures for the high use scenario.

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5 This latter factor merits further discussion. As was discussed in Section III, the percentage of total projected use accounted for by dry bulk commodities (farm products, metallic ores, and coal) increases dramatically from 25 percent in 1977 to 42 percent in 2003. Since these commodities typically move in tows and vessels that approach the maximum accommodated tow and vessel sizes given the varying channel dimensions of each waterway segment, the weighted-average linehaul costs reported in Table V-1 reflect the shift to these relatively low cost movements (on a per ton-mile basis) and away from the relatively high cost movements (on a per ton-mile basis) of other commodities.

Table V-3

National Evaluation Report
High Use Scenario

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		976.4	1,117.9	1,162.7	1,262.4	1,357.0	1,477.9	1,532.9
Foreign		938.5	975.8	1,044.2	1,034.3	1,110.2	1,145.5	1,194.3
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.5	98.0	97.0
Foreign		100.0	100.0	100.0	100.0	99.4	98.8	98.6
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.8	98.6	97.4
Foreign		100.0	100.0	100.0	100.0	99.7	99.3	99.2
Domestic Energy Traffic vs. Consumption of Energy Products	percent	40.5	43.6	39.8	34.5	31.6	29.4	27.0
Average Linehaul Costs	$/tonmile							
National		0.0059	0.0057	0.0062	0.0064	0.0069	0.0075	0.0079
Inland		0.0083	0.0085	0.0091	0.0091	0.0095	0.0102	0.0107
Great Lakes		0.0026	0.0025	0.0026	0.0027	0.0027	0.0029	0.0030
Coastal		0.0018	0.0017	0.0018	0.0019	0.0020	0.0021	0.0022

1. Traffic Accommodation. Under the high use scenario, total domestic waterborne traffic increases from 976.4 million tons in 1977 to 1,516.4 million tons in 2003, for a compound annual growth rate of 1.8 percent -- compared to 1.5 percent growth under the Baseline Scenario. Foreign traffic increases to 1,197.7 million tons, for a compound growth of 0.9 percent per year, .2 percent per year faster than in the base-line forecast.

Once again, a comparison of total traffic relative to projected usage reveals a short-term problem with domestic waterborne movements in 1985 before the new 1,200' chamber at L&D 26 on the Upper Mississippi is brought on stream. The short-falls in lock capacity in 1995 and beyond, however, are substantially greater than those under the baseline scenario. A total of 17 million tons of foreign commerce and another 42 million tons of domestic commerce are not accommodated by the present system.

The national evaluation report for the High Use Scenario also indicates that constraining locks limit more than two percent of domestic energy shipments. This exceeds the limitations encountered under the baseline scenario.

Waterborne energy products traffic declines to near 28 percent of domestic consumption by the year 2003,

co~pared to 41 percent in 1977. Heavy dependence on the waterways for petroleum movement, primarily imports at coastal ports, coupled with substantial substitution away from oil as a fuel in the forecast period are responsible for the declining importance of waterways in energy traffic.

Figure V-B shows the constraining locks hindering movement of both foreign and domestic traffic. The locks on the Welland Canal section of the seaway act as constraints on United States foreign commerce by 1995, five years earlier than under the baseline scenario. Additional Ohio River (Uniontown) and Warrior River (Holt, Warrior, and Oliver) locks are identified as at or exceeding capacities by the year 2003, further restricting waterborne foreign and domestic traffic to levels two or three percent below projected usage.[6]

Once again, there is a much larger set of locks where increased traffic congestion may merit replacement in advance of a physical short fall in capacity. Table V-4 lists these locks.

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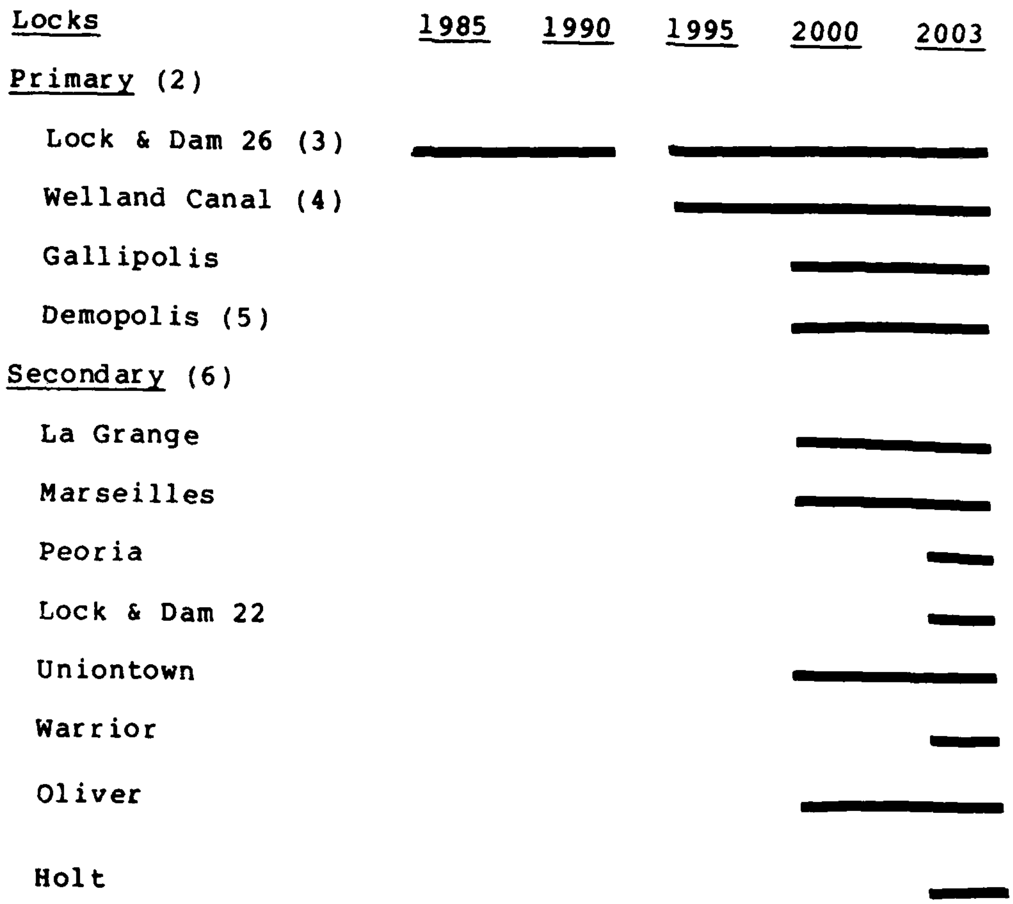
6 It should be noted the additional coal flows were added to the High Use Scenario after the location of the proposed synfuel plant was made public in 1980 on the Monongahela and Upper Ohio Rivers. The increased tonnage due to the proposed synfuel plant is discussed in Section III. Increased lock congestion and delays at Monongahela and Ohio locks will result from this increased traffic. However, these flows did not result in a shortfall in lock capacity. The reasons were that: 1) the larger average tow size improved chamber utilization and increased capacity and 2) these particular coal flows, which were moving in the opposite direction of the major coal flows, increased the percentage of loaded barges at the affected locks and increased lock capacity. This finding emphasizes the need for future lock capacity studies to take into account "system-wide" effects of new commodity flows.

Figure V-B

NWS Constraining Locks: (1)
High Use Scenario



NOTES:
(1) Capacity is reached or exceeded by projected usage in 2003.
(2) Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.
(3) New 1,200' by 100' chamber is completed in 1990.
(4) Locks 1, 2, 3, 7 and 8 only.
(5) Much of the traffic which is constrained at Demopolis is traffic which would use the Tennessee-Tombigbee Waterway. Since an alternative routing is available to this traffic, it may not actually be diverted from the system altogether. However, it is worth noting that the alternative routing also uses three "problem" locks: Locks and Dam 52 on the Ohio, Lock and Dam 53 on the Ohio, and Inner Harbor Lock on the Gulf Intracoastal Waterway East.
(6) Constraining only if additional capacity is provided for the primary (controlling) locks.

Table V-4

Other Locks With Increased Congestion: High Use Scenario

Region	Lock
Lower Upper Mississippi	L&D 27
Upper Mississippi	L&D 16, 17, 18, 19, 20, 21, 24 and 25
Illinois	Starved Rock Dresden Island Lockport
Ohio	Newburgh McAlpine Dashields Emsworth Montgomery
Tennessee	Kentucky
GIWW West	Harvey Algiers
GIWW East	Inner Harbor
Tombigbee-Alabama-Coosa-Black Warrior	Coffeeville
Great Lakes/ St. Lawrence Seaway	St. Mary's River Locks
Columbia-Snake Waterway	Bonneville

2. <u>Linehaul Costs</u>. Real operating costs do not change substantially from the Baseline results, with the exception of Great Lakes/Seaway shipments. The linehaul costs for inland shipments actually decline slightly relative to the value for the baseline scenario, because the increased costs from lock delays are off-set by the reduction in the weighted-average costs of all inland shipments due to the larger proportion of coal traffic moving at relatively low ton-mile costs.

(c) Low Use Scenario

Table V-5 presents the values of key national measures for the overall system from 1977 to 2003.

Table V-5

National Evaluation Report
Low Use Scenario

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		976.4	1,110.6	1,147.1	1,184.4	1,238.4	1,294.1	1,333.2
Foreign		938.5	952.0	1,004.9	967.6	1,002.2	1,004.4	1,046.6
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.8	100.0	99.9	99.3	99.8
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	100.0	99.7	99.5
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Domestic Energy Traffic vs. Consumption of Energy Products	percent	40.5	41.8	39.4	36.7	34.7	31.7	30.3
Average Linehaul Costs	$/tonmile							
National		0.0059	0.0058	0.0063	0.0066	0.0071	0.0078	0.0081
Inland		0.0083	0.0085	0.0090	0.0092	0.0097	0.0104	0.0109
Great Lakes		0.0026	0.0025	0.0025	0.0027	0.0028	0.0029	0.0030
Coastal		0.0018	0.0017	0.0018	0.0019	0.0020	0.0021	0.0022

1. <u>Traffic Accommodation</u>. The low use scenario has domestic waterborne traffic growing at the rate of 1.2 percent per year, with foreign commerce increasing at a 0.4 percent rate -- both substantially slower increases than under the baseline scenario. During the forecast period, domestic traffic not served remains near one percent of total projected usage. A relatively small amount (15 million tons) of domestic tonnage is not accommodated by the present system, but all foreign traffic is accommodated.

Just as in the case of the other two scenarios discussed above, waterway shipments of energy products (coal, petroleum products, and crude petroleum) as a percent of total energy consumption declines.

Constraining locks are shown in Figure V-C. Lock and Dam 26 on the Mississippi River is a consistent problem throughout the forecast period, although construction by 1990 of a new, single chamber facility alleviates the problem until 1995, when a second chamber is likely to be needed. This finding with regard to Lock and Dam 26 is all the more startling in view of the substantially lower corn export shipments under the low use scenario compared to other scenarios. By the year 2003, capacities at the LaGrange and Marseilles locks on the Illinois River, the Gallipolis lock on the Ohio River, and the Demopolis and Oliver facilities on the Warrior River system are forecast to fall short of projected usage as well.

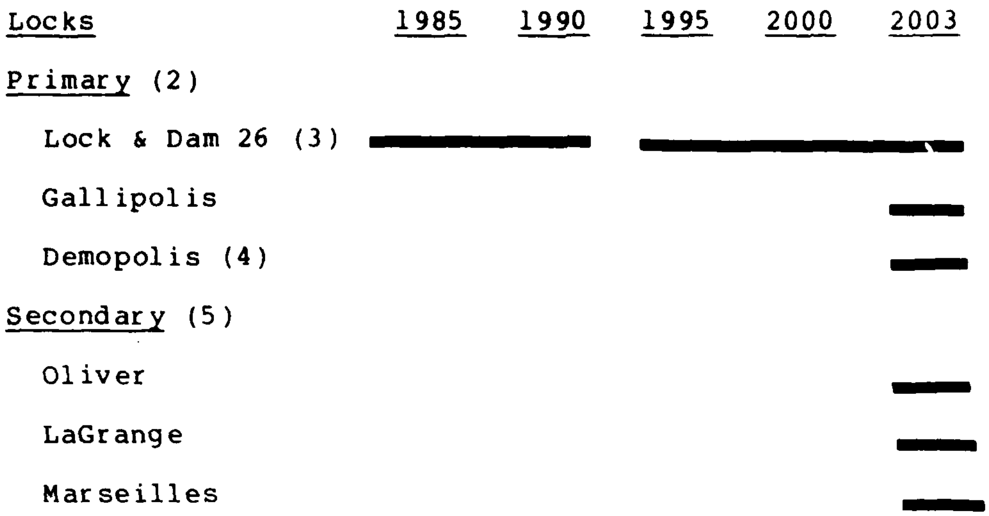
The higher imports of steel products under the low use scenario explain in part why the capacities of the Demopolis and Oliver facilities fall short of projected usage.

As might be expected, a smaller set of locks are potential candidates for replacement based on project-level analysis of benefits and costs. Table V-6 presents these locks. It should be noted that, despite the markedly lower corn shipments under the low use scenario, five locks on the Upper Mississippi and three locks on the Illinois River still have significant increases in delay times.

2. Linehaul Costs. The cost increases for domestic shipments are in line with those expected under the baseline scenario. The delays at the Well and Canal and the Seaway locks force the real costs of Great Lakes/Seaway traffic to grow faster than the costs for inland and coastal traffic. However, delays at Lock and Dam 26 along with other Upper Mississippi and Illinois locks cause the costs of inland shipments to increase faster than those for all coastal shipments.

Figure V-C

NWS Constraining Locks: (1)
Low Use Scenario



NOTES: (1) Capacity is reached or exceeded by projected usage in 2003.

(2) Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

(3) New 1,200' by 10' chamber is completed in 1990. The existing 110' x 600' and 100' x 360' constrains until replaced by the authorized single 110' x 1,200' chamber. The new chamber, in turn, becomes constraining in 1995.

(4) Much of the traffic which is constrained at Demopolis is traffic which would use the Tennessee-Tombigbee Waterway. Since an alternative routing is available to this traffic, it may not actually be diverted from the system altogether. However, it is worth noting that the alternative routing also uses three "problem" locks: Locks and Dam 52 on the Ohio, Lock and Dam 53 on the Ohio, and Inner Harbor Lock on the Gulf Intracoastal Waterway East.

(5) Constraining only if additional capacity is provided for the primary (controlling) locks.

Table V-6

Other Locks With Increased Congestion:
Low Use Scenario

Region	Lock
Upper Mississippi	L&D 19, 20, 21, 22, 24 and 25
Illinois	Peoria Starved Rock Lockport
Ohio	Uniontown McAlpine Emsworth
Tennessee	Kentucky
GIWW East	Inner Harbor
Tombigbee-Alabama-Coosa-Black Warrior	Warrior Holt
Great Lakes/ St. Lawrence Seaway	St. Mary's River Welland Canal*
Columbia-Snake Waterway	Bonneville

NOTE: Utilization exceeds 99% of practical capacity, but falls short of 100%.

(d) Bad Energy Scenario

Table V-7 presents the values of key national measures for the Bad Energy Scenario.

1. Traffic Accommodation. The bad energy scenario, as indicated earlier, reflects a more rapid evolution of world industry away from the use of petroleum as a primary fuel. Thus, both total industry output as well as energy use is affected. Domestic waterborne traffic increases at 1.5 percent per year to the year 2003, slightly slower than under the baseline forecast. Lower potential output growth due to technological lags in

Table V-7

National Evaluation Report
Bad Energy Scenario

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		976.4	1,115.3	1,158.3	1,246.9	1,313.7	1,363.7	1,428.5
Foreign		938.5	980.1	1,054.5	1,030.7	1,048.3	1,029.0	1,085.8
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.1	99.4	99.3	98.9	97.2
Foreign		100.0	100.0	99.8	99.3	99.1	98.9	98.3
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.7	99.8	99.7	99.6	98.3
Foreign		100.0	100.0	99.9	99.7	99.5	99.3	98.9
Domestic Energy Traffic vs. Consumption of Energy Products	percent	40.5	41.9	39.4	37.9	36.0	32.9	1.1
Average Linehaul Costs	$/tonmile							
National		0.0059	0.0058	0.0063	0.0066	0.0070	0.0077	0.0081
Inland		0.0083	0.0085	0.0090	0.0091	0.0095	0.0102	0.0107
Great Lakes		0.0026	0.0025	0.0026	0.0027	0.0027	0.0029	0.0029
Coastal		0.0018	0.0017	0.0018	0.0019	0.0020	0.0021	0.0022

introducing new equipment and facilities not dependent on petroleum fuels is the primary reason behind the slower economic growth. Foreign traffic increases at 0.6 percent per year in the bad energy scenario, indicative of slower overall growth in the world economy due to much higher energy prices.

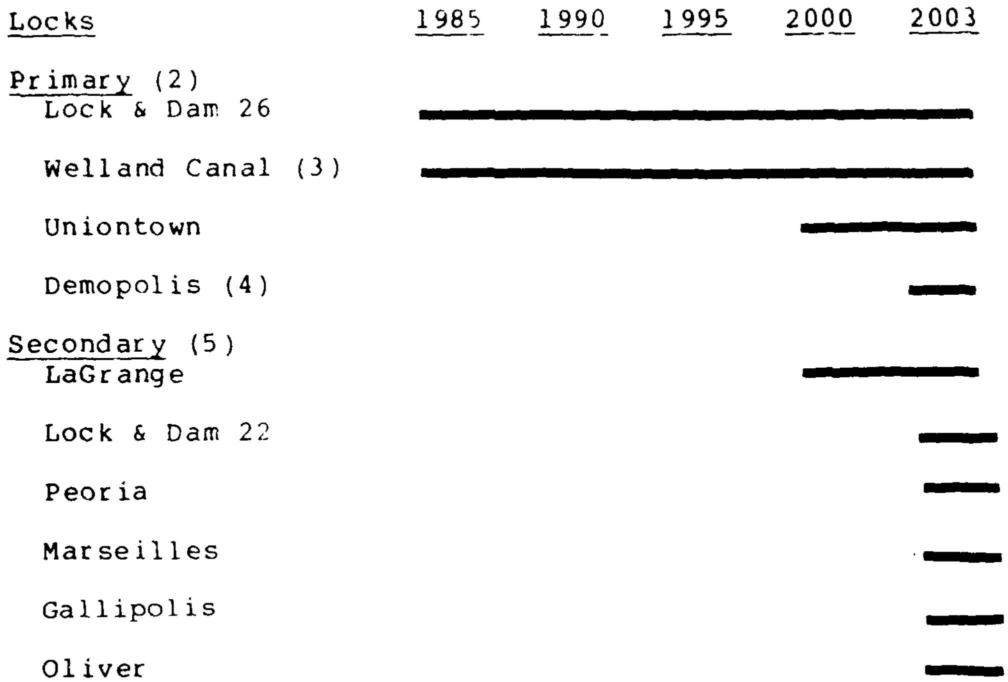
A comparison of total traffic handled relative to projected usage reveals continuous problems from 1985 onwards for both domestic and foreign shipments. The overall shortfall in lock capacity by the year 2003 is comparable to the shortfall under the high use scenario. An estimated 34 million tons of domestic shipments and another 18 million tons of foreign shipments are not accommodated by the present system during 2003.

In addition, approximately one percent of energy shipments (both foreign and domestic) are not accommodated by the system.

Figure V-D shows the constraining locks under the bad energy scenario.

Figure V-D

NWS Constraining Locks: (1) Bad Energy Scenario



NOTES:
(1) Capacity is reached or exceeded by projected usage in 2003.
(2) Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.
(3) Locks 1, 2, 3, 7 and 8 only.
(4) Much of the traffic which is constrained at Demopolis is traffic which would use the Tennessee-Tombigbee Waterway. Since an alternative routing is available to this traffic, it may not actually be diverted from the system altogether. However, it is worth noting that the alternative routing also uses three "problem" locks: Locks and Dam 52 on the Ohio, Lock and Dam 53 on the Ohio, and Inner Harbor Lock on the Gulf Intracoastal Waterway East.
(5) Constraining only if additional capacity is provided for the primary (controlling) locks.

Lock and Dam 26 is a persistent problem throughout the forecast period due to the higher shipments of grain from Illinois and Upper Mississippi River points to the Baton Rouge -- New Orleans area. Projected usage also exceeds the capacities of five of the Welland Canal facilities in 1985 and beyond. This problem is also due in part to increased overseas grain shipments.

By 2000, the LaGrange lock on the Illinois River and the locks at Uniontown on the Ohio River are constraining. By 2003, Lock and Dam 22 on the Upper Mississippi; Peoria and Marseilles Locks on the Illinois; Gallipolis on the Ohio; and Demopolis and Oliver on the Warrior constrain waterborne shipments.

Table V-8 lists those locks where increased traffic congestion and delays may justify replacement in advance of a physical shortfall in capacity based on delays.

2. Linehaul Costs. Real linehaul cost increases affect primarily inland systems in the forecast period. Heavy growth in coal traffic is a major reason for the higher congestion and the resultant increases in delay costs.

(e) Sensitivity Analysis

Several sensitivity analyses were conducted during the course of the evaluation of the present navigation system. These analyses evaluated the sensitivity forecasts summarized in Section III and examined selected locks in greater detail. These are discussed in turn.

1. Defense Forecast. All of the sensitivity forecasts were treated as modifications to the High Use Scenario. The purpose in doing so was to see if additional locks would become constraining or if any previously identified constraining locks would constrain earlier.

Table V-8

Other Locks With Increased Congestion: Bad Energy Scenario

Region	Lock
Lower Upper Mississippi	L&D 27
Upper Mississippi	L&D 16, 17, 18, 19, 20, 21, 24 and 25
Illinois	Starved Rock Lockport
Ohio	Newburgh McAlpine Emsworth Montgomery Dashields
Tennessee	Kentucky
GIWW West	Harvey Algiers
GIWW East	Inner Harbor
Tombigbee-Alabama-Coose-Black Warrior	Warrior Holt
Great Lakes/St. Lawrence Seaway	St. Mary's River Locks

Except for the Great Lakes, the present system is capable of handling most flows under the postulated emergency. The following locks are constraining in 1990 under the defense forecast:[7]

- St. Mary's River Locks on the Great Lakes
- Gallipolis on the Upper Ohio.
- Marseilles on the Illinois.

By far and away, the single most important constraint is the lack of lock capacity at the St. Marys River between Lakes Superior and Huron. A shortfall in annual throughput capacity of nearly 70 million tons occurs at this point in 1990. With massive new requirments for steel, projected movements of metallic ores on the Great Lakes jump from 56.3 billion ton-miles in 1985 to 151.4 billion ton-miles in 1990, an increase of nearly 200 percent. Such a shortfall in lock capacity indicates that the United States would have serious problems in moving raw materials to United States mills during a wartime production period.

The shortfalls in capacity at Marseilles and Gallipolis are much less severe. In both cases, approximately 2 million tons of traffic cannot be accommodated. The increased flows of steel, chemicals, and petroleum related to war production activity greatly increase the utilization of these chambers.

Finally, Table V-9 presents a list of locks where delays increase significantly during the height of the conflict in 1990. As can be seen, there is severe lock congestion through-out the Upper Ohio River, and the entire Illinois River as well as at key points such as Lock and Dam 26 and the Welland Canal section of the St. Lawrence Seaway.

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7 It is interesting to note that, with the completion of the new chamber at Lock and Dam 26, there is just barely enough lock capacity to handle waterborne flows in 1990. Thus, the new chamber is fully utilized during its first year of operation under the assumed defense emergency condition.

Table V-9

Other Locks With Increased Congestion: Defense Forecast

Region	Lock
Lower Upper Mississippi	Lock and Dam 26
Upper Mississippi	Lock and Dam 22
Illinois	LaGrange Peoria Starved Rock Dresden Island Lockport
Ohio	McAlpine Montgomery Dashields Emsworth
Tennessee	Kentucky
GIWW West	Harvey Algiers
GIWW East	Inner Harbor
Tombigbee-Alabama-Coosa-Black Warrior	Oliver
Great Lakes/St. Lawrence Seaway	Welland Canal

2. <u>High Coal Exports</u> Constraining locks under this forecast are shown in Figure V-E. The major differences between the High Use and High Coal Export forecasts in terms of constraining locks occur on the Tombigbee-Warrior River System, the Ohio River and the Gulf. Heavy increases in downbound coal from the Tennessee and Warrior River systems put tremendous strain on the Tombigbee-Warrior River System locks, beginning in 1990 with Oliver. By 1995, the Demopolis lock also reaches 100% utilization. The Coffeeville and Holt facilities reach their capacity limits by the year 2000 if capacity is added at Demopolis and Oliver under the High Export scenario, with high delays developing by the late 1990s. Finally, in 2003, the Bankhead facility reaches capacity assuming that constraints in the rest of this system are relieved. Projected usage at all Warrior and Tombigbee River locks reach or exceed capacity under the High Coal Export forecast by the end of the study period. Higher coal exports via Mobile, Alabama are the major reason for the capacity problems at Tombigbee-Warrior River locks.

Again, relative to the High Use scenario, the Innerharbor lock reaches capacity (assuming that additional lock capacity is provided at other sites with significant traffic interaction) in the year 2003 due to increased export coal traffic projections on the Mississippi River.[8] By 2003, almost 4% of the projected tonnage at this lock cannot be handled.

Finally, higher coal traffic on the Ohio River for export, relative to the High Use scenario results in the Newburgh and McAlpine locks exceeding capacity limits in the year 2003 (assuming that additional capacity is added at Gallipolis) with projected use exceeding estimated capacity by less than one percent.[9]

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8 All three of these locks have substantial delays under other scenarios.

9 All three of these locks have substantial delays under other scenarios.

Figure V-E

NWS Constraining Locks: (1) High Coal Exports Scenario

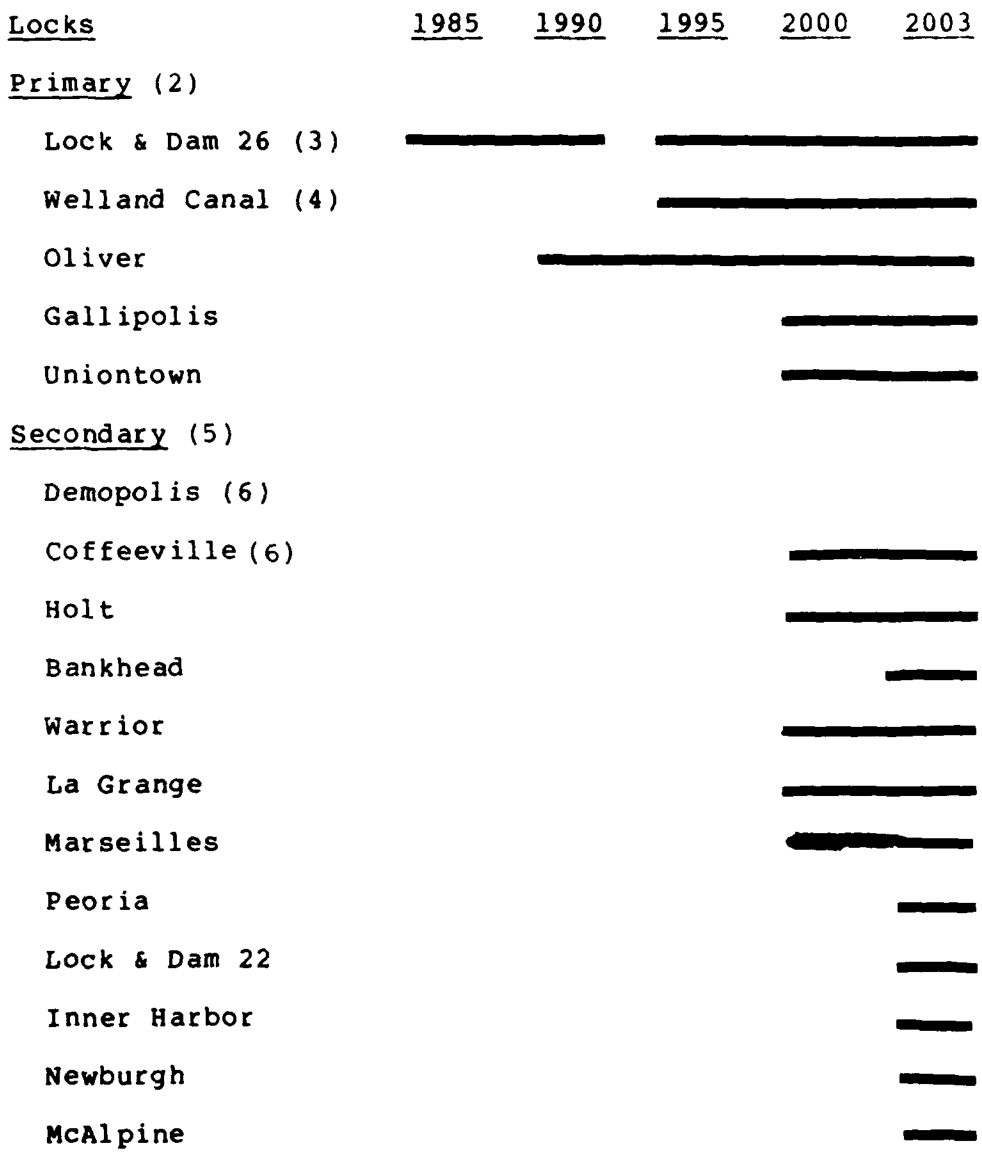

Figure V-E
(Continued)

NWS Constraining Locks: High Coal Exports Scenario

NOTES:
(1) Capacity is reached or exceeded by projected usage in 2003.
(2) Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.
(3) New 1,200' by 100' chamber is completed in 1990.
(4) Locks 1, 2, 3, 7 and 8 only.
(5) Constraining only if additional capacity is provided for the primary (controlling) locks.
(6) Much of the traffic which is constrained at Demopolis and Coffeeville is traffic which would use the Tennessee-Tombigbee Waterway. Since an alternative routing is available to this traffic, it may not actually be diverted from the system altogether. However, it is worth noting that the alternative routing also uses three "problem" locks: Locks and Dam 52 on the Ohio, Lock and Dam 53 on the Ohio, and Inner Harbor Lock on the Gulf Intracoastal Waterway East.

3. "Other" Adjustments. As might be expected, the findings with regard to lock constraints differ somewhat under this sensitivity analysis. The following differences between this analysis and the High Use scenario occurred:

(a) Inner Harbor Lock capacity on the GIWW East is reached in 1985. (The data adjustment which results in this conclusion would also cause this lock to become a constraint under all scenarios during the study period.)

(b) Bonneville Lock capacity on the Upper Columbia is reached in 1990.

(c) Gallipolis Lock on the Upper Ohio reaches capacity in 1995 (five years earlier than the High Use scenario).

(d) McAlpine Lock on the Ohio reaches capacity in 2000 (assuming that additional capacity is added at Gallipolis).

(e) Montgomery lock on the Upper Ohio also reaches capacity in 2003 (assuming that additional capacity is added at Gallipolis).

No shortfalls in lock capacity took place on the Arkansas River and the Monongahela River.

4. Lock Capacity Analysis. The basic lock capacity calculations under the High Use scenario were examined for a few selected locks to review the effects of changed assumptions or different mixes of actions to increase capacity. These analyses are presented in detail in Appendix E and are summarized below.

a. Minor Structural Actions. Appendix E presents an analysis of the possible impacts on capacity of selected site specific, minor structural actions based on unique site characteristics. Such actions would possibly be taken by the Corps of Engineers on the basis of project-level analysis. The NWS equation for lock capacity did not incorporate such actions and investigation of such actions is beyond the original scope of the NWS.

The locks involved are Lock and Dam 22 on the Upper Mississippi, Marseilles Lock on the Illinois, and the Welland Canal locks of the St. Lawrence Seaway.

The findings of this analysis are:

- Minor structural actions at Lock and Dam 22 could possibly delay the period at which the lock becomes a physical constraint, assuming that a second 1200' by 110' chamber is constructed at Lock and Dam 26. Lock and Dam 22 was found to be constraining under the Baseline and High Use scenarios in 2003.

- Minor structural actions at Marseiiles could possibly delay the period at which the lock becomes a physical constraint, assuming that there is adequate capacity at Lock and Dam 26. Marseilles was found to be constraining under all four scenarios by 2003.

- Minor structural actions at the Welland Canal locks, if proven effective in field studies, could possibly delay the period at which these locks become a physical constraint. These locks were found to be constraining under three of the four scenarios.

b. Recreational Usage at Selected Locks. In response to a comment at the November 1980 public meetings, the effect of allowing for continued recreational usage of locks at base period levels on the Mississippi River and Illinois Waterway was examined to see if any additional locks would be constrained under the High Use scenario. No additional locks were constrained and the conclusions remain unchanged.

c. Restricted Navigation Seasons. The effect of less than year round navigation on the Upper Mississippi, and the Great Lakes-St. Lawrence Seaway, was examined to see if season extensions would change the conclusions about whether or not locks would be constraints under the High Use scenario. In all cases season extensions would provide significant increases in capacity. However, this finding is significant only for the Great Lakes-St. Lawrence Seaway. For this region, season extension may remove all capacity constraints under the High Use scenario. Season extension would provide relief but would not remove the capacity constraint at the St. Mary's River locks under the defense emergency sensitivity. These different conclusions have to be tempered in that neither locks nor vessels operate as efficiently in winter as in other seasons. However, this level of detail was not reviewed.

d. Open Pass Conditions. The effect of open pass conditions at two sites, Calcasieu Lock on the Gulf Intracoastal Waterway and Locks and Dams 52 on the Ohio River was examined to see if a different treatment of open pass conditions at these sites would change the conclusions regarding constraints under the High Use scenario. Calcasieu Lock was found not to constrain traffic even in the total absence of open pass conditions. Locks and Dam 52 was found to be a potential constraint under the High Use scenario.

INDUSTRY EVALUATION

In order to examine the impacts on major water transportation users, the 14 NWS reporting commodities were aggregated to seven industry sectors:

1. Agriculture (includes farm and food products).

2. Fertilizer/Chemicals.

3. Steel (includes metallic ores and primary metal products).

4 Coal.

5. Petroleum (includes crude petroleum and petroleum products).

6. Forest Products (includes lumber and wood products, pulp, paper and products).

7. Other (includes nonmetallic minerals; stone, clay, glass, and concrete products; waste and scrap; and other).

This evaluation focuses on the commercial users of water transportation. The present system's ability to accommodate current and projected waterborne traffic affects these industries directly. The industry measures are:

1. Projected usage not accommodated due to lock capacity constraints for each of seven waterborne industries.

2. Share of domestic waterborne traffic as a percentage of total supply for each seven waterborne industries.

3 Average costs of linehaul operations for domestic shipments of seven waterborne industries.

The findings with regard to each industry are discussed below.

(a) Agriculture

1. Traffic Accommodation. Domestic projected usage for this industry increases from 65 million tons in 1977 to 123 million tons under the Low Use Scenario and 35 million tons under all other scenarios by 2003. For all scenarios except the Low Use scenario, agricultural waterborne traffic continues to be one of the fastest growing commodities during the forecast period, having a 3.0% annual compound rate of growth for the Baseline scenario.

Exports of grain and grain products increase from 137 million tons in 1977 to 296 million tons under the Low Use scenario and 329 million tons under the Bad Energy scenario by 2003. For the Baseline scenario, grain export traffic grows at a 3.5% annual compound rate.

Table V-10 compares agricultural traffic versus projected usage by NWS scenario. The percentage of domestic projected usage not accommodated is the highest for Bad Energy. Under the Bad Energy scenario, nearly 15 percent of domestic projected usage in 2003 cannot be accommodated. This traffic not accommodated exceeds 19 million tons in 2003. However, even under the Low Use scenario, over 6 percent of domestic projected usage cannot be acommodated in the year 2003. This traffic not accommodated is nearly 8 million tons in 2003.

Generally, only 1 to 2% of the projected usage of exports of grain and grain products cannot be accommodated by the present system due to shortfalls in the capacities of the Welland Canal. All foreign traffic is accommodated during the entire forecast period under the Low Use scenario, but as much as 6 million tons are not accommodated under the Bad Energy scenario in the year 2003.

The shortfall in lock capacity at Lock and Dam 26 (even with the construction of the new 1200' by 110' chamber) is the principal reason for the large number of tons of domestic projected usage that cannot be accommodated.

Table V-10

Agriculture Traffic Handled Versus
Projected Usage by NWS Scenario

	1985	1990	1995	2000	2003
Baseline					
Domestic	99%	100%	96.6%	91.3%	89.4%
Foreign	100	100	100.0	99.8	99.5
High Use					
Domestic	99	100	96.6	91.4	89.3
Foreign	100	100	99.3	98.6	98.4
Low Use					
Domestic	98.6	100	95.2	92.6	93.5
Foreign	100	100	100	100	100
Bad Energy					
Domestic	93.9	95.5	95.0	92.6	85.5
Foreign	99.7	99.0	98.8	98.8	98.2

Major waterway regions originating domestic agricultural traffic for export are the Upper Mississippi, Lower Upper Mississippi, Illinois and Ohio Rivers and the Columbia-Snake Waterway. Very little agricultural traffic is not accommodated on the Ohio River and the Columbia-Snake Waterway has sufficient lock capacity at Bonneville (potentially the most constraining lock) under all four scenarios to accommodate domestic agricultural traffic. But, a shortfall in lock capacity at Lock and Dam 26 limits domestic agricultural shipments from the Upper Mississippi, Lower Upper Mississippi and Illinois Rivers.

For the Upper Mississippi River, projected usage under the Baseline scenario rises from 13.2 million tons in 1977 to 33.3 million tons by the year 2003. As much as 22% of the projected usage in agriculture for the region can not be handled in 2003 due to the shortfall in capacity of the new chamber at Lock and Dam 26.

Projected usage in agriculture for the Lower Upper Mississippi grows from 36.0 to 78.6 million tons in 2003 under the Baseline scenario. The shortfall in capacity at Lock and Dam 26 limits actual agricultural traffic to 82% of projected usage in 2003.

Projected usage in agriculture for the Illinois River increases from 16.0 to 31.1 million tons during the forecast period. However, due to the shortfall in capacity at Lock and Dam 26, only 78 percent of the projected usage in 2003 can be accommodated.

Finally, the shortfall in capacity at Lock and Dam 26 also affects the amount of grain terminating in the Baton Rougeto-Gulf region. Due to this up-river constraint, over 20 percent of projected terminations do not even reach the region in 2003, under the Base scenario.

2. Domestic Traffic Versus Total Industrial Supply. Under all four scenarios, the share of domestic agricultural traffic as a percent of United States production in creases. Under the Baseline scenario, this share increases from 18% to 25 percent. Thus, despite the shortfalls in capacity at Lock and Dam 26, the reliance on the waterways for the agriculture industry is projected to increase.

3. Linehaul Costs. On average, domestic linehaul costs per ton-mile increase from 4.3 mills to 6.8 mills (in 1977 dollars) by 2003 under the Baseline scenario. This rate of increase is somewhat faster than that for other industries and reflects the substantial lock delays on the Lower Upper Mississippi, Upper Mississippi, and Illinois Rivers as well as the lock delays at the Welland Canal and the St. Lawrence River.

4. Other Scenarios. The variations in projected use for this industry vary from the Baseline only under the Low Use and Bad Energy scenarios. In general Agriculture fares better under Low Use. Under the Bad Energy scenario agriculture fares worse than in any other scenario, with 24 million tons not accommodated. Other measures do not vary significantly across scenarios.

(b) Fertilizer/
Chemicals

1. Traffic Accommodation. In general, waterborne fertilizer/chemical tonnage originates on the Gulf Intracoastal Waterways and Lower Mississippi River and terminates upstream at receiving facilities.

Domestic projected usage for these industries increases from 46.1 million tons in 1977 to 89.8 million tons under the Low Use Scenario and 95.1 million tons under the other scenarios in 2003. This is an annual compound rate of growth of approximately 3 percent.

Foreign projected usage for these industries increases from 31.7 million tons to approximately 41.9 million tons in 2003 at a relatively slow annual rate of growth (1.1%).

In sharp contrast to the agriculture industry, only a relatively small percentage of domestic chemical/fertilizer flows cannot be accommodated (See Table V-11).

Table V-11

Fertilizer/Chemical Traffic Handled
Versus Projected Usage by NWS Scenario

	1985	1990	1995	2000	2003
Baseline					
Domestic	99.7%	100%	99%	97.1%	96.2%
Foreign	100	100	100	100	100
High Use					
Domestic	99.7	100	99.1	96.4	95.0
Foreign	100	100	99.9	99.9	99.9
Low Use					
Domestic	99.6	100	99.8	98.5	97.8
Foreign	100	100	100	100	100
Bad Energy					
Domestic	98.3	98.8	98.6	97.9	95.4
Foreign	100	100	100	99.9	99.9

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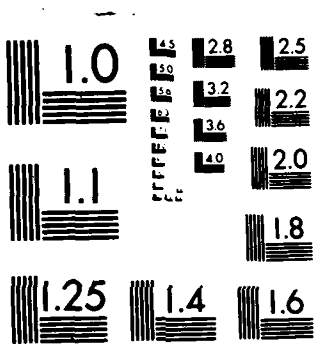

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Under the Baseline Scenario, an estimated 3.6 million tons of waterborne chemical/fertilizer shipments cannot be handled in 2003. The majority of these unaccommodated shipments, approximately 2.7 million tons, are due to Lock and Dam 26, the remaining shipments are limited by the shortfall in capacity of Gallipolis Lock on the Upper Ohio.

Once again, in contrast to the agriculture industry, no locks constrain the foreign shipments of chemicals/fertilizers during the forecast period.

Gulf Coast West originations of chemical/fertilizer tonnage are projected to double during the forecast period to 42 million tons. But, approximately 2 percent of these flows cannot be accommodated due to up-river lock constraints.

Gulf Coast East originations are only 20 percent of those for the Gulf Coast West, but the impact of up-river lock constraints is nearly identical to that of the GIWW West. Approximately 1 to 2% of these flows cannot be accommodated in 2003.

Projected usage of the Lower Mississippi and Baton Rouge-to-Gulf regions is affected more dramatically by the upriver lock constraints. An estimated 10 percent of these flows cannot be accommodated due to lock capacity shortfalls in 2003.

With regard to terminations, Illinois River chemical/fertilizer flows are expected to fall 20% below projected usage due to lock constraints. Ohio River chemical/fertilizer flows are projected to double to 18.7 million tons, but 5% of these flows cannot be accommodated in 2003. Upper Mississippi River terminations are projected to grow to 5.1 million tons from 2.1 million tons in 1977, but 20% of these terminations cannot be accommodated.

2. Linehaul Costs. On average, domestic linehaul costs per ton-mile increase from 7.9 mills to 1.8 mills (in 1977 dollars) an increase below that of the agriculture industry both in percent and in absolute amounts.

3. Other Scenarios. In general this evaluation measures for this industry do not vary significantly across the other scenarios.

(c) Steel

1. Traffic Accommodation. Domestic projected usage for the steel industry increases from 61.5 million tons in 1977 to 129.2 million tons under the Low Use scenario and 152.8 million tons under the Baseline and High Use scenarios in 2003. Much of this domestic traffic is iron ore moving on the Great Lakes.

Foreign projected usage for the steel industry increases from 88.1 million tons in 1977 to 148-150 million tons in 2003. This traffic represents imported steel products as well as imported iron ore.

Table V-12 compares steel traffic versus projected usage by NWS scenario. As can be seen, nearly all of the projected domestic flows can be accommodated by the present system. Few problems are anticipated in moving iron ore from Lake Superior to Lake Erie destinations, since the locks at St. Mary's River have just enough capacity to accommodate projected flows.

Domestic shipments of steel products are constrained mainly by Lock and Dam 26 and also by Gallipolis Lock. Under the Baseline scenario, only 91 percent of the projected 10.7 million tons on the Lower Mississippi River can be accommodated in 2003 by up-river locks. Similar problems occur on the Lower Upper Mississippi (82% of the projected 5.0 million tons can be accommodated); the Baton Rouge-to-Gulf area (92% of the projected 11.2 million tons); the Illinois River (95% of 16.2 million tons); and the Ohio River (92% of 8.4 million tons).

Table V-12

Steel Traffic Handled Versus Projected Usage by NWS Scenario

	1985	1990	1995	2000	2003
Baseline					
Domestic	99.9%	100%	99.8%	99.3%	99.1%
Foreign	100	100	100	99.4	98.6
High Use					
Domestic	99.9	100	99.8	99.1	98.8
Foreign	100	100	98.0	96.1	95.7
Low Use					
Domestic	99.9	100	100	99.7	99.5
Foreign	100	100	100	100	100
Bad Energy					
Domestic	99.6	99.7	99.7	99.6	99.2
Foreign	99.2	97.4	96.9	96.6	95.2

With regard to foreign tonnage, the present system does quite well under the Baseline and Low Use scenarios. However, under the High Use and Bad Energy scenarios, the Welland Canal locks limit actual imported iron ore and steel products traffic to 96 to 95 percent of projected usage, respectively. Thus, an estimated seven million tons of foreign shipments cannot be accommodated in 2003 under either of these two scenarios.

Significant increases in domestic and foreign steel shipments take place in the Mobile River and Tributaries Region, with total domestic traffic tripling during the forecast period and foreign traffic more than doubling. Yet, lock capacity of the system is almost adequate to accommodate flows through the year 2003. (While traffic is almost entirely accommodated, domestic linehaul costs increase by 1.8% per year on the system, well above the national average for all steel shipments.)

2. Domestic Traffic Versus Total Supply. Waterborne shipments of the steel industry in 1977 as a percent of total supply (United States production plus imports) were unusualy low in 1977 (namely 28 percent) due to the western ore miners' strike. This share increases to 39 percent by 1980 and remains relatively constant thereafter under three of the four scenarios. However,

the increasing reliance of the U.S. on imported steel in the Low Use scenario results in a declining share of domestic waterborne shipments as a percent of total supply to approximately 6.1 percent by 1995 and thereafter.

3. Linehaul Costs. On average, domestic linehaul costs (including Great Lakes and inland movements) per ton-mile increase by a third from 3.4 mills in 1977 to 4.7 mills (in 1977 dollars) in 2003. This rate of increase is well below that of the agriculture industry both in terms of percentage and absolute increase. But, it should be noted that, due to increasing lock congestion and delays on the Great Lakes/St. Lawrence Seaway, domestic linehaul costs for the steel industry increase from 1.6 mills in 1977 to 2.1 mills in 2003 for an annual compound rate of growth of 1.1 percent.

4. Defense Requirements. Since the steel industry is a key industry for national defense, it is important to note that it is uniquely affected by the lock capacity shortfalls at the St. Mary's River Locks in the Great Lakes Region. Under the Defense Scenario in 1990, only 77.5% of domestic waterborne tonnage for this industry could be accommodated under the Defense Scenario. This is a shortfall of 57 million tons for this industry under the assumed conditions.

(d) Coal

1. Traffic Accommodation. Coal traffic is expected to be the major growth commodity over the next quarter century for domestic waterborne flows. Under the Baseline scenario, projected coal usage for domestic termination grows from 156.3 million tons in 1977 to 403.1 million tons by 2003, for a compound growth rate of 4.0% per year. Foreign trade in coal is expected to increase by 2.7% per year to 111 million tons per year by 2003.

Table V-13 compares coal traffic versus projected usage by NWS scenario. Few short-term problems are expected under any scenario, but terminal facilities at Atlantic and Gulf Coasts are limiting U.S. exports of coal at the present time. It is expected that the large number of terminal expansion plans will greatly alleviate this problem. At the end of the forecast period the present system is able to accommodate coal flows reasonably well under the Baseline, Low Use and Bad Energy scenarios. Traffic not accommodated is less than 2 percent total flows in 2003.

Table V-13

Coal Traffic Handled Versus
Projected Usage by NWS Scenario

	1985	1990	1995	2000	2003
Baseline					
Domestic	99.9%	100%	99.7%	98.7%	98.0%
Foreign	100	100	100	99.7	99.2
High Use					
Domestic	99.9	100	99.7	97.7	96.0
Foreign	100	100	98.9	97.8	97.5
Low Use					
Domestic	99.9	100	100	99.6	99.2
Foreign	100	100	100	100	100
Bad Energy					
Domestic	99.5	99.7	99.6	99.5	97.4
Foreign	99.6	98.5	98.2	98.1	97.2

However, the system does not handle the coal flows under the High Use scenario nearly as well. As much as 3.5% of total domestic coal flows are not handled in 2003 under the High Use scenario. And, under both the High Use and Bad Energy scenarios, the Welland Canal and locks limit United States exports of coal to Canada (over two percent of foreign coal trade cannot be accommodated in 2003 under the High Use scenario). These disruptions are comparable to those of the agriculture industry.

Coal flows in a variety of regions are affected by capacity shortfalls at Lock and Dam 26, Gallipolis, and Demopolis. Under the High Use scenario, as much as 10% of the projected 22.3 million tons of coal flows for the Upper Mississippi River cannot be accommodated in 2003 due to Lock and Dam 26. Coal flows on the Lower Upper Mississippi are also affected by the shortfall at Lock and Dam 26. As much as 8 percent of the 46.6 million tons of projected usage under the High Use scenario cannot be

accommodated in 2003. As might be expected, the shortfall at Lock and Dam 26 also limits terminations on the Illinois River. As much as 7 percent of the 22.1 million tons of domestic coal flows in 2003 on the Illinois cannot be accommodated.

However, the single largest disruption of coal flows occurs on the Ohio River due to the Gallipolis and Uniontown locks. As much as 5 percent of the 265.9 million tons of projected coal flows cannot be accommodated in 2003. These Ohio River constraints also affect the Tennessee River flows. As much as 12 percent of the projected 56.9 million tons for this region cannot be accommodated in 2003.

Coal flows are also disrupted in the Alabama-Tombigbee-Black Warrior Loan Region due to a series of lock capacity shortfalls, the principal one of which is Demopolis. An estimated 11 percent of the 53.6 million tons for this region cannot be accommodated in 2003.

2. Share of Domestic Traffic Versus Total Supply. For all four scenarios, waterborne shipments as a percent of total supply decline. The decline from 25 percent in 1977 is most severe under the High Use scenario. In 2003, waterborne traffic accounts for little more than 19% of total United States coal production in spite of the large increases in coal traffic. The declining share is attributable in part to construction of new coal-fired plants in areas poorly served by the present waterways system. The rail share and possibly the share of coal-slurry pipelines in these shipments can be expected to increase throughout the time period.

3. Linehaul Costs. Linehaul costs of domestic traffic increase from 5.1 mills per ton-mile to 7.4 mills (in 1977 dollars) per ton-mile in 2003 under the baseline scenario. This rate of increase is in line with that of the agriculture industry and reflects the higher costs of increasing lock delays.

4. High Coal Exports. As described in Section III an additional forecast predictated on much higher exports of coal was developed. The present system does not handle this additional tonnage well. By 2003 31.7 million tons are not accommodated compared to 17 million tons under High Use. The most important shortfalls occur in the Ohio Region at Gallipolis and Uniontown.

(e) Petroleum

1. Traffic Accomodation. Whereas coal is expected to be the major growth commodity for the waterway system in the next quarter century petroleum is just the opposite. Under the Baseline Scenario, conservation and fuel substitution are expected to result in a 0.5% per year decline in petroleum flows on the domestic system, while petroleum imports are expected to fall by 1.8% per year to 2003. Petroleum flows decline under all three other scenarios as well.

Table V-14 compares petroleum traffic with projected usage during the forecast period and by NWS scenario. As can be seen, expected lock capacity shortfalls have little impact on the petroleum industry. Less than one percent of domestic usage cannot be accommodated in 2003. In the worst case, the High Use Scenario, the result is less than three million tons of disrupted domestic shipments.

Table V-14

Petroleum Traffic Handled Versus Projected Usage by NWS Scenario

	1985	1990	1995	2000	2003
Baseline					
Domestic	100%	100%	99.9%	99.6%	99.4%
Foreign	100	100	100.0	100.0	100.0
High Use					
Domestic	100	100	99.9	99.5	99.2
Foreign	100	100	100	100	100.2
Low Use					
Domestic	100	100	100	99.8	99.7
Foreign	100	100	100	100	100
Bad Energy					
Domestic	99.8	99.9	99.8	99.7	99.4
Foreign	100	100	100	100	100

No locks constrain foreign shipments of crude petroleum or petroleum products.

Most petroleum traffic on the inland waterways originates along the GIWW and Lower Mississippi River, following distribution patterns similar to chemicals. Some problems exist in reaching up-river destinations in the forecast period. For example although Upper Mississippi petroluem traffic is nearly constant at 3.5 million tons to 2003 under the Baseline scenario, the shortfall in traffic by 2003 approaches 14%. Similarly, shortfalls occur on the Lower Upper Mississippi and the Illinois River (down 15%), but only a 5% shortfall exists on the Ohio River.

Under the Bad Energy scenario, the average shortfall in petroleum traffic by river segment increases by 2% to 3% in the year 2003.

Although petroleum traffic increases by 2 million tons to 12.1 million tons by 2003 under the Baseline scenario on the Tombigbee-Alabama-Coosa-Black Warrior region, projected shortfalls are expected to be less than 1% of usage. Major increases in crude oil traffic are expected along the California Coast due to Alaskan flows, but no capacity problems are anticipated. An introduction of deep-draft, offshore oil terminals at the Gulf in the 1980s will reduce present port congestion due to oil imports.

2. Share of Domestic Traffic Versus Total Supply. Waterborne shipments of petroleum and petroleum products as a percent of total supply are expected to increase slightly from 1977 (51%) to 1985 (58 to 60%) and then to decline to 2003 (46 to 48%). The expected peak in domestic petroleum shipments from Alaska in 1985 temporarily increases the reliance of the petroleum industry on water transportation. But, the decline in these shipments coupled with increased competition from pipeline gradually result in a modest reduction in the petroleum industry's reliance on water transportation.

3. Linehaul Costs. On average, domestic line-haul costs per ton-mile increase from 4.9 mills to 6.3 mills (in 1977 dollars). This rate of increase is one of the slowest for any industry both in absolute and percentage terms. The increase reflects higher costs of fuel

offset in part by improved fuel utilization. Lock delays, which affect the grain and coal industries most directly, are not important factors in determining the increase in ton-mile costs of linehaul operations for the petroleum industry.

(f) Forest Products

1. Traffic Accommodation. Domestic projected usage under the Baseline scenario increases from 27.3 million tons in 1977 to 36.3 million tons in 2003. Foreign usage is projected to decline slightly from 37.1 million tons in 1977 to 34.2 million tons in 2003. The great majority of waterborne forest products traffic is concentrated along the Washington/Oregon Coast and on the Columbia/Snake Waterway. No significant problems under any scenario are expected for these movements. Some shortfalls due to Lock and Dam 26 constraints are possible, although all are less than 0.5% of projected usage.

Movement of the forest products industry to the Southeast coupled with increased use of the waterways under the High Use scenario could result in some congestion problems in the 1990s. However, the actual shortfalls are expected to be miniscule, compared to problems with the coal traffic on southeastern river systems.

2. Linehaul Costs. Domestic marine linehaul costs of forest products shipments increase on average from 4.2 mills to 6.0 mills per ton-mile (in 1977 dollars) during the forecast period. This increase reflects the real cost increases of fuel, but no significant increases in delay times. Once again, this increase falls well below those for the grain and coal industries both in percentage and absolute terms.

(g) Other

This grouping is a catch-all and includes non-metallic minerals (principally sand and gravel); stone, clay, glass and concrete products; waste and scrap; and other commodities (principally manufactured goods in foreign trade).

Table V-15 compares other traffic with projected usage for these commodities. As can be seen, very little tonnage is not accommodated by the present system even in the year 2003.

Table V-15

Other Traffic Handled Versus
Projected Usage by NWS Scenario

	1985	1990	1995	2000	2003
Baseline					
Domestic	100%	100%	99.9%	99.5%	99.4%
Foreign	100	100	100	99.9	99.8
High Use					
Domestic	100	100	99.9	99.4	99.2
Foreign	100	100	99.8	99.6	99.6
Low Use					
Domestic	100	99.9	100	99.8	99.7
Foreign	100	100	100	100	100
Bad Energy					
Domestic	99.7	99.8	99.8	99.7	99.4
Foreign	99.9	99.7	99.7	99.6	99.5

On average, the linehaul cost for domestic marine shipments of other commodities increases from 11.7 mills per ton-mile in 1977 to 14.4 mills per ton-mile in 2003, a substantial increase in absolute terms but modest in percentage terms.

REGIONAL EVALUATION

This evaluation of the present system focuses on these measures:

(1) Projected usage not accommodated by the present system due to lock capacity constraints.

(2) Increase in traffic by 2003 from 1977.

(3) Average tow size divided by maximum accommodated tow size for inland waterways.

(4) Hazardous commodities (crude petroleum, petroleum products, chemicals, and fertilizers) as a share of total commodity flows.

(5) Average delay at locks.

The last four measures can be used to highlight those regions with potential safety problems in the future arising from changes in traffic mix and absolute increases in traffic.

The findings with regard to each of the 22 regions are discussed briefly below, but only the baseline scenario is examined in detail and the discussion concentrates on those regions with major traffic change by the year 2003.

The focus of the discussion on the Baseline Scenario is not meant to imply any special merit for the Baseline Scenario over other scenarios. Rather, the baseline is presented only as a benchmark for discussion. Where significant differences occur across scenarios these are discussed.

(a) Upper Mississippi

Under the Baseline scenario, Upper Mississippi River waterborne traffic increases 24 million tons from 1977 to 2003. Problems with Locks and Dam 26 congestion as well as Lock and Dam 22 severely limit traffic growth beyond 1995. By 2003, less than 83% of projected usage can be accommodated (see Table V-16).

The increasing congestion at all locks (but especially Locks 16 through 22, 24, and 25) results in a sharp increase in average delay per tow, posing a safety problem. By 2003 average tow delay approaches 22 hours.

Table V-16

Regional Evaluation Report
Scenario: Baseline
Region: Upper Mississippi River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		30.9	39.5	44.7	48.9	56.9	63.5	66.0
Foreign		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	98.3	100.0	94.5	86.0	82.8
Foreign		NC	NC	NC	NC	NC	NC	NC
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	98.8	100.0	96.4	91.0	89.0
Foreign		NC	NC	NC	NC	NC	NC	NC
Average Linehaul Costs	$/ton mile	0.0075	0.0076	0.0081	0.0083	0.0090	0.0102	0.0108
Increase in Traffic From 1977	million tons	0.0	8.6	13.0	18.1	22.9	23.7	23.8
Average/Maximum Tow Size	percent	52.2	56.3	59.4	60.9	62.9	62.7	63.1
Hazardous Commodities	percent	18.8	17.0	14.5	14.1	13.3	13.7	13.1
Average Delay at Locks	hours	3.2	5.3	6.4	6.4	9.9	17.5	21.7

The increasing share of coal and grain traffic which typically moves in large tows, as a percent of total traffic results in an increase in average tow size during the forecast period. Average tow size increases approximately 20% and some loss in tow maneuverability can be expected. This is especially a problem for this region, given the large number of old restrictive bridges in this region.

The share of hazardous commodities declines uniformly through the period, thus, the severity of potential accidents may well be reduced.

The navigation system performs significantly better in this region under the Low Use scenario due to projected use that is about 11% lower. The performance does not vary significantly across other scenarios.

(b) Lower Upper Mississippi

Under the Baseline scenario, the Lower Upper Mississippi waterborne traffic increases 60 million tons by 2003. But, the single 1200' by 110' chamber at Lock and

Dam 26 completed by 1990 does not provide sufficient capacity to handle all projected flows in 1995 and beyond. By 2003; only 85% of projected usage can be accommodated (see Table V-17).

Table V-17

Regional Evaluatic.. Report
Scenario: Baseline
Region: Lower Upper Mississippi River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		77.5	90.0	101.9	113.3	134.2	153.5	162.0
Foreign		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	98.4	100.0	95.0	87.8	85.0
Foreign		NC	NC	NC	NC	NC	NC	NC
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	98.7	100.0	96.6	92.3	90.7
Foreign		NC	NC	NC	NC	NC	NC	NC
Average Linehaul Costs	$/ton mile	0.0081	0.0094	0.0120	0.0092	0.0104	0.0110	0.0115
Increase in Traffic From 1977	million tons	0.0	12.5	22.7	35.8	50.0	57.2	60.3
Average/Maximum Tow Size	percent	32.9	35.1	36.5	37.2	38.7	39.2	39.3
Hazardous Commodities	percent	25.4	23.7	20.9	19.8	18.2	17.4	16.8
Average Delay at Locks	hours	1.6	3.1	5.9	2.0	3.1	3.6	3.9

Tow delays increase through 1985, after which the completion of the new chamber at Lock and Dam 26 reduces average delays for a few years.

Tow size increases approximately 25% during the time period, once again reflecting the increase in grain and coal traffic. However the average remains well below the maximum accommodated tow size.

The share of hazardous commodities declines throughout the period, reducing the potential severity of accidents.

As in the Upper Mississippi Region, the system in this region is less congested under the Low Use Scenario due to significantly lower volumes of traffic.

(c) Lower Mississippi

The Lower Mississippi traffic is predominantly through traffic. There are no locks to constrain traffic, but all the projected use for the region cannot be accommodated due to up-river constraints. These constraints (principally Lock and Dam 26) become severe in 1995 and beyond. By 2003, less than 91% of projected usage is accommodated by the present system (See Table V-18).

Table V-18

Regional Evaluation Report
Scenario: Baseline
Region: Lower Mississippi River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		123.6	138.2	155.5	157.5	185.2	210.3	222.3
Foreign		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traffic vs. Projected Usage	percent							
Domestic		107.0	100.0	99.2	100.0	97.2	92.7	90.8
Foreign		NC	NC	NC	NC	NC	NC	NC
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.8	100.0	99.4	98.0	97.2
Foreign		NC	NC	NC	NC	NC	NC	NC
Average Linehaul Costs	$/ton mile	0.0050	0.0051	0.0054	0.0057	0.0059	0.0063	0.0066
Increase in Traffic From 1977	million tons	0.0	14.6	30.7	33.9	56.5	71.5	78.3
Average/Maximum Tow Size	percent	27.9	29.7	31.6	33.3	35.3	36.2	36.7
Hazardous Commodities	percent	34.6	32.3	29.1	27.1	24.8	23.6	22.9
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Tow sizes increase over 33%, but remain well below the maximum accommodated tow sizes.

The share of hazardous commodities decline throughout the period.

The volume of traffic varies significantly in this region across all the forecasts, but the evaluation measures do not vary significantly from the baseline due to the absence of locks.

(d) Baton Rouge to Gulf

In the Baton Rouge to Gulf region, total waterborne traffic increases by 166.4 million tons from 1977 to 2003, an increase of 3.2% per year. Constraints at up-river

locks on the Lower Upper Mississippi, Illinois and Ohio Rivers restrict traffic flows to 93% of projected usage by the year 2003 (See Table V-19).

Table V-19

Regional Evaluation Report
Scenario: Baseline
Region: Baton Rouge to Gulf

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		187.3	210.6	224.3	233.3	261.3	291.1	303.2
Foreign		157.1	182.4	197.8	189.6	210.9	220.6	231.6
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.5	100.0	98.1	94.9	93.5
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.7	98.9	98.5
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0057	0.0058	0.0062	0.0065	0.0070	0.0077	0.0080
Increase in Traffic From 1977	million tons	0.0	48.6	74.2	75.5	119.6	148.7	166.6
Average/Maximum Tow Size	percent	28.2	29.2	30.8	31.4	32.2	32.0	32.7
Hazardous Commodities	percent	53.4	52.2	46.6	42.8	39.3	35.4	34.7
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The mix of foreign and domestic traffic in the region poses safety problems and these problems are heightened by the 48% increase in total traffic by 2003.

The share of hazardous commodities is very high at the beginning of the period, but does decline from 1980-2000. However, the 35% share is one of the highest hazardous commodity shares of all of the 22 regions.

As in the Lower Mississippi Region Traffic levels vary significantly across scenarios but other measures do not vary greatly due to the absence of locks.

(e) Illinois Waterway

Illinois Waterway traffic increases by 30 million tons over the forecast period, or a 2.2% per year growth. Restrictions at Lock and Dam 26, Lagrange, Peoria, and Marseilles locks hold traffic growth to 86% of domestic projected usages and 95% of foreign commerce by the year 2003. (See Table V-20).

Table V-20

Regional Evaluation Report
Scenario: Baseline
Region: Illinois Waterway

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		54.3	60.9	67.2	70.3	79.7	87.0	91.8
Foreign(1)		6.1	6.7	7.9	8.4	9.8	11.1	11.7
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	98.7	100.0	95.6	68.7	86.1
Foreign		100.0	100.0	100.0	100.0	100.0	97.8	95.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.1	100.0	97.1	92.7	91.1
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0072	0.0071	0.0074	0.0077	0.0081	0.0091	0.0094
Increase in Traffic From 1977	million tons	0.0	7.1	13.9	18.2	25.4	28.3	29.7
Average/Maximum Tow Size	percent	36.2	37.9	39.5	40.2	42.2	43.0	43.2
Hazardous Commodities	percent	21.9	19.7	17.8	18.0	16.9	16.2	15.9
Average Delay at Locks	hours	1.4	1.6	2.2	2.7	4.4	7.8	8.4

NOTE: (1) Includes Port of Chicago Great Lakes traffic.

The system in this region is less congested under the Low Use scenario but does not vary significantly for other scenarios from the baseline. The system becomes slightly constrained under the Defense scenario due to higher levels of iron and steel traffic.

Average delay at locks increases dramatically after 1990, posing potential safety problems in and around lock chambers.

Average tow size increases approximately 20 percent, but the average remains well below the maximum accommodated tow size.

The share of hazardous commodities declines modestly during the period, reducing the potential severity of accidents.

(f) Missouri River

Growth in traffic and projected usage is nearly flat for this river. The relatively high ton-mile costs and limited season discourage shippers from relying on the Missouri as part of their water-based logistics systems (see Table V-21).

Table V-21

Regional Evaluation Report
Scenario: Baseline
Region: Missouri River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		6.7	7.3	7.4	7.3	7.4	7.7	7.8
Foreign		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.8	100.0	99.3	98.0	97.6
Foreign		NC	NC	NC	NC	NC	NC	NC
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	98.1	100.0	93.7	84.1	80.4
Foreign		NC	NC	NC	NC	NC	NC	NC
Average Linehaul Costs	$/ton mile	0.0162	0.0166	0.0179	0.0190	0.0203	0.0218	0.0226
Increase in Traffic From 1977	million tons	0.0	0.5	0.7	0.6	0.6	0.8	0.9
Average/Maximum Tow Size	percent	56.4	59.4	60.7	62.1	63.2	64.2	66.0
Hazardous Commodities	percent	14.5	14.2	14.7	16.1	16.8	16.9	16.4
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

There are no locks on the river, but the interaction with the rest of the system limits the amount of traffic that can be accommodated by 2003 to 98%.

Average tow size is high in relation to the maximum tow size and this average increases by 16% during the forecast period, posing possible maneuverability problems for the many bends of the Missouri.

(g) Ohio River

The Ohio River waterborne traffic growth is substantial, increasing 129 million tons from 1977 to 2003, despite constraining locks in the region (Gallipolis and Uniontown) and some traffic interaction with other regions with constraining locks (principally Lock and Dam 26). Lock constraints in the region and in the rest of the system limit traffic to 97% of projected usage in 2003 (see Table V-22).

The assumption of a nuclear moratorium in the high use scenario greatly increases use of the Ohio River as does the High Coal Export sensitivity analysis.

Table V-22

Regional Evaluation Report
Scenario: Baseline
Region: Ohio River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		172.5	179.5	212.2	229.1	262.6	292.5	307.5
Foreign		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.8	98.3	97.0
Foreign		NC	NC	NC	NC	NC	NC	NC
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	99.8	98.5	97.3
Foreign		NC	NC	NC	NC	NC	NC	NC
Average Linehaul Costs	$/ton mile	0.0087	0.0089	0.0090	0.0089	0.0092	0.0098	0.0102
Increase in Traffic From 1977	million tons	0.0	7.1	39.7	57.1	91.2	117.7	129.1
Average/Maximum Tow Size	percent	48.7	49.6	53.8	57.5	60.2	61.7	62.5
Hazardous Commodities	percent	22.1	21.7	18.3	16.1	15.0	14.6	14.3
Average Delay at Locks	hours	1.1	1.2	1.6	2.0	3.0	4.2	4.9

Average delay at locks increases during the time period but remains below those delays of the Upper Mississippi and Illinois Rivers.

Average tow size increases sharply, going up over 34% during the time period, reflecting the faster rate of growth in coal traffic which typically moves in large tows. These increases in average tow size, traffic levels, and delays can be expected to increase the safety problems in the region if offsetting actions such as enchanced vessel traffic services at river junctions and locks are not taken.

These potential increases in safety problems are only partially offset by a reduction in the share of hazardous commodities.

Projected use and tonnage accommodated varies significantly in this region across all forecasts depending on the amount of coal attempting to use the river. Safety measures also vary somewhat. Average linehaul costs are somewhat lower with higher volumes of traffic due to the dominance of coal which is relatively cheap to handle. Projected use is also substantially higher under the

"Other Adjustments" forecast to account for data base errors.

(h) Tennessee River

The trends evident in the Ohio River region apply equally to the Tennessee River. Growth in traffic increases sharply after 1985, reflecting the completion of the Tennessee - Tombigbee Waterway. From 1977 to 2003, traffic increases over 165% (see Table V-23). Lock constraints in other regions limit traffic in 2003 to 98% of projected use.

Table V-23

Regional Evaluation Report
Scenario: Baseline
Region: Tennessee River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		26.5	26.9	27.3	40.9	52.1	61.5	66.9
Foreign		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.8	100.0	99.6	98.9	98.5
Foreign		NC	NC	NC	NC	NC	NC	NC
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.8	99.4	99.1
Foreign		NC	NC	NC	NC	NC	NC	NC
Average Linehaul Costs	$/ton mile	0.0097	0.0100	0.0107	0.0100	0.0098	0.0101	0.0104
Increase in Traffic From 1977	million tons	0.0	0.3	0.9	14.1	24.3	32.2	36.5
Average/Maximum Tow Size	percent	31.9	32.3	32.1	41.3	45.4	47.6	48.7
Hazardous Commodities	percent	20.9	21.4	22.6	19.0	16.5	15.6	15.2
Average Delay at Locks	hours	0.7	0.7	0.7	0.6	0.8	1.2	1.5

Average tow size increases over 50%, once again reflecting the surge in coal traffic from the completion of the Tennessee - Tombigbee Waterway. Such a sharp increase in tow size can pose maneuverability problems in the future. However, average delay at locks is low even though delays double and hazardous commodities represent a relatively small share of total traffic.

Projected use and all the evaluation measures except linehaul cost vary significantly across all forecasts. Tonnage accommodated is severely impacted under High Use, High Coal Exports, and "Other Adjustments" Due to constraints in other regions.

(i) Arkansas River

Projected usage of the Arkansas increases a modest 5 million tons during the forecast period. No locks within the region constrain traffic, but traffic interaction with Lock and Dam 26 limits traffic to 99% of projected usage in 2003 (see Table V-24).

Table V-24

Regional Evaluation Report
Scenario: Baseline
Region: Arkansas River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		9.4	9.7	10.0	11.3	12.8	14.0	14.4
Foreign		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.6	99.0	98.7
Foreign		NC	NC	NC	NC	NC	NC	NC
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.7	100.0	99.3	98.4	98.0
Foreign		NC	NC	NC	NC	NC	NC	NC
Average Linehaul Costs	$/ton mile	0.0144	0.0147	0.0154	0.0153	0.0157	0.0165	0.0169
Increase in Traffic From 1977	million tons	0.0	0.3	0.6	1.9	3.4	4.5	4.9
Average/Maximum Tow Size	percent	36.3	37.6	40.4	46.5	49.6	51.6	52.4
Hazardous Commodities	percent	28.6	28.0	25.6	21.6	19.4	17.6	17.0
Average Delay at Locks	hours	0.2	0.2	0.3	0.6	0.9	1.2	1.3

Average tow size increases over 44% during the forecast period, potentially increasing the region's safety problem. This factor, however, is more than offset by declining shares of hazardous commodities, modest lock delays, and little overall increase in traffic.

Projected use was also explicitly modified upwards for this region under the "Miscellaneous Sensitivities" forecast to take account alternative projections from other studies. The only evaluation measure for the present system which is significantly different for this region is delays at locks which increases more than threefold.

(j) Gulf Coast West

Traffic increases over 42 million tons by 2003. No locks constrain traffic growth during the period and limited traffic interaction with constraining locks in other regions has a small effect on reducing growth in use (see Table V-25).

Table V-25

Regional Evaluation Report
Scenario: Baseline
Region: Gulf Coast West

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		168.8	180.8	162.1	167.8	172.8	179.3	186.6
Foreign		172.5	197.8	202.2	185.7	194.9	189.9	199.1
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.7	99.1	98.8
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	99.9	99.6	99.4
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0114	0.0116	0.0129	0.0137	0.0146	0.0158	0.0166
Increase in Traffic From 1977	million tons	0.0	37.4	22.8	12.2	25.9	26.5	42.2
Average/Maximum Tow Size	percent	54.1	54.1	54.2	54.8	55.1	55.3	55.4
Hazardous Commodities	percent	79.2	78.5	74.7	71.1	69.2	65.9	64.6
Average Delay at Locks	hours	0.1	0.1	0.1	0.1	0.2	0.2	0.2

The most important factor bearing on the safety of this region is the high level of hazardous commodities traffic. Although this share declines by 18%, it remains very high. Safety actions such as enhanced vessel traffic services may be justified simply on the high share of hazardous traffic in this region.

(k) Gulf Coast East

Domestic projected usage is projected to increase by 47 million tons and there are no constraining locks in the region to limit traffic growth (under the "other" sensitivity analysis, Inner Harbor Navigation Canal Lock limits traffic growth). Table V-26 presents measures for the region.

The ratio of average tow size to maximum accommodated tow size is relatively high at the beginning of the period and increases by nearly 18% during the study period.

Table V-26

Regional Evaluation Report
Scenario: Baseline
Region: Gulf Coast East

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		69.4	69.2	76.8	91.9	103.4	114.8	116.7
Foreign		39.2	43.9	48.9	42.8	40.3	36.7	35.4
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	99.9	99.8	99.8
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	99.9
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0108	0.0111	0.0117	0.0123	0.0130	0.0136	0.0145
Increase in Traffic From 1977	million tons	0.0	3.7	16.3	25.4	34.2	41.9	42.5
Average/Maximum Tow Size	percent	51.0	50.8	54.2	56.3	58.4	59.6	59.9
Hazardous Commodities	percent	50.4	50.7	45.4	41.2	38.0	34.4	34.3
Average Delay at Locks	hours	0.2	0.2	0.3	0.2	0.3	0.3	0.4

The share of hazardous commodities as a percent of total traffic is also high at the beginning of the period. This share declines by a third, but is still relatively high in 2003. Thus, additional safety problems could develop in this region without offsetting actions such as enhanced vessel traffic services.

Projected use was also modified substantially for this region under the "Other Adjustments" analysis. This is one of two regions where the adjustment resulted in another lock (namely Inner Harbor) becoming constraining that was not found to be constraining under any other scenario. Consequently all measures are worse for this region under this forecast than under the Baseline, except the share of hazardous commodities.

(1) Mobile River and and Tributaries

For the Mobile River and Tributaries Region, the completion of the Tennessee/Tombigbee Waterway in the late 1980's combined with other growth results in an increase in total traffic of 75.6 million tons by the

year 2003, for an average annual increase of 4.1% per year. Under the baseline scenario, lock constraints in the region develop late in the period so that total overall traffic disruptions are limited (see Table V-27).

Table V-27

Regional Evaluation Report
Scenario: Baseline
Region: Mobile River and Tributaries

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		30.0	30.7	33.5	56.2	66.7	76.5	82.7
Foreign		13.7	16.7	19.9	24.3	28.9	33.3	36.3
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	99.9	99.8
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	99.9
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0108	0.0112	0.0118	0.0112	0.0113	0.0120	0.0127
Increase in Traffic From 1977	million tons	0.0	3.7	9.7	36.7	51.8	66.0	75.1
Average/Maximum Tow Size	percent	82.9	83.0	85.0	95.3	98.9	100.4	100.9
Hazardous Commodities	percent	26.2	24.5	21.0	20.1	17.9	16.3	15.6
Average Delay at Locks	hours	0.3	0.3	0.5	1.1	1.4	2.3	3.5

Increasing lock congestion results in increases in average tow delays. By 2003, average delays are 3.5 hours, up from 0.4 hours in 1977. The very high ratio of average to maximum tow size increases even more during the study period. The sharp increase in traffic, increasing lock congestion, and high tow sizes in relation to channel dimensions suggest that this region will experience safety problems without offsetting actions. (One proposal involves channel widening of the Tombigbee River south of the junction with the Warrior River and this action has been incorporated in NWS Strategy IV.)

The performance of the navigation system in this region varies widely across all the forecasts ranging from 99% of domestic tonnage accommodated under Low Use to only 85% accommodated under High Coal Exports. Other evaluation measures also fluctuate significantly although a consistent pattern of a steadily worsening situation emerges as new stresses are applied. It is mainly a matter of how rapidly the situation will change.

(m) Atlantic Coast Regions

In general, waterborne traffic remains steady, or slightly declines along the Atlantic Coast, due to reductions in coastwise petroleum flows. For the Middle Atlantic coast segment, rapid increases in coal exports offsets these oil trafffic losses (see Tables V-28, V-29, V-30). The only variation across scenarios in these regions is the rate of growth of coal exports across scenarios.

Table V-28

Regional Evaluation Report
Scenario: Baseline
Region: South Atlantic Coast

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		40.4	40.1	37.0	36.2	35.6	35.1	35.7
Foreign		29.3	29.3	30.9	31.3	31.9	32.7	33.9
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0019	0.0019	0.0020	0.0021	0.0022	0.0023	0.0024
Increase in Traffic From 1977	million tons	0.0	-0.4	-1.8	-2.2	-2.2	-2.0	-0.2
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	70.3	67.5	61.9	57.9	54.0	49.6	47.8
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table V-29

Regional Evaluation Report
Scenario: Baseline
Region: Middle Atlantic Coast

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		211.3	214.2	197.8	197.9	199.6	195.8	198.4
Foreign		225.4	225.1	227.3	222.7	231.2	231.9	239.7
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0019	0.0019	0.0020	0.0022	0.0023	0.0024	0.0025
Increase in Traffic From 1977	million tons	0.0	2.6	-11.6	-16.2	-6.0	-9.0	1.3
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	70.9	68.7	61.7	57.3	52.8	47.0	45.0
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table V-30

Regional Evaluation Report
Scenario: Baseline
Region: North Atlantic Coast

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		52.1	53.4	46.5	45.7	43.9	40.8	40.0
Foreign		35.3	29.0	32.3	32.6	31.6	28.4	29.0
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0018	0.0018	0.0019	0.0020	0.0021	0.0023	0.0023
Increase in Traffic From 1977	million tons	0.0	-4.9	-8.6	-9.1	-11.8	-18.2	-18.5
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	92.0	90.5	86.3	83.0	81.3	78.0	77.0
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The share of hazardous commodities in these regions in total traffic declines throughout the period, but the levels are still relatively high in 2003. This is especially true of the oil dependent North Atlantic region. Accordingly, actions to reduce the likelihood of tanker accidents are entirely appropriate in these regions.

(n) Great Lakes,
St. Lawrence Seaway,
N.Y. State Waterways

Substantial problems are expected to arise in Great Lakes/St. Lawrence Seaway traffic over the forecast period. Total traffic is expected to increase by 191 million tons, including both coal flows for domestic and Canadian destinations and exports of grains. By the year 2003, foreign traffic is a little more than 46% of projected usage. Capacity falls short of projected use for the Welland Canal locks of the Seaway, (see Table V-31).

Table V-31

Regional Evaluation Report
Scenario: Baseline
Region: Great Lakes-St. Lawrence Seaway-New York State WW

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		126.9	169.2	184.3	200.9	223.7	247.8	263.5
Foreign		63.0	75.1	86.8	93.8	103.8	114.6	122.2
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	99.9	99.8	99.7
Foreign		100.0	100.0	100.0	100.0	100.0	98.4	96.4
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	99.9	100.0	99.8	99.4	99.2
Foreign		100.0	100.0	100.0	100.0	100.0	99.0	97.8
Average Linehaul Costs	$/ton mile	0.0026	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030
Increase in Traffic From 1977	million tons	0.0	54.4	81.2	104.8	137.4	170.2	190.7
Average/Maximum Tow Size	percent	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hazardous Commodities	percent	6.8	5.2	4.2	3.7	3.2	2.8	2.7
Average Delay at Locks	hours	1.6	2.2	3.2	3.3	4.6	6.0	6.8

Average vessel delays at locks increase sharply after 1980 and delays are not limited to the St. Lawrence Seaway. Substantial delays occur at the St. Mary's River locks as well.

The substantial increase in traffic and delays are reasons for considering possible actions to enhance water transportation safety in the region.

This region is unique among the regions analyzed in that foreign traffic (predominantly export grains and imported metallic ores and iron and steel products) are most affected by lock constraints under the various scenarios. Substantial increases in traffic are projected in all scenarios although actual levels vary widely. Evaluation measures vary widely but also portray a steadily worsening situation across all scenarios.

This region is also the most severely affected by the defense scenario, although the constraint point shifts from the Welland Canal to the St. Mary's River Locks. The navigation system in this region simply is inadequate under that scenario.

(o) Washington-Oregon Coast

Increased receipts of Alaskan oil as well as increased foreign trade make this coastal region one of the few with sizable traffic gains during the period. This increased traffic and sharp jump in hazardous commodities share in the early 1980's suggest that some enhanced vessel traffic services may be appropriate for this region (see Table V-32).

Table V-32

Regional Evaluation Report
Scenario: Baseline
Region: Washington-Oregon Coast

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		30.3	44.2	61.8	64.1	66.1	63.7	62.8
Foreign		38.1	33.3	53.3	52.0	56.6	56.7	58.4
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0022	0.0021	0.0021	0.0022	0.0023	0.0024	0.0025
Increase in Traffic From 1977	million tons	0.0	9.1	46.8	47.7	54.4	52.1	52.8
Average/Maximum Tow Size	percent	NC	NC	NC	[illegible]	NC	NC	NC
Hazardous Commodities	percent	38.6	38.3	56.4	56.9	57.0	52.5	50.9
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(p) Columbia/Snake-Willamette River

Traffic increases 15 million tons by 2003. There are no constraining locks to limit the growth of traffic under all four NWS scenarios, however, the inclusion of a major, relatively long-haul sand and gravel movement from above Bonneville Lock and Dam to Portland results in a shortfall in lock capacity by 1990 under the "Miscellaneous Sensitivities" forecast (see Table V-33).

(q) California Coast

The increased receipts of Alaskan oil just offset the decline in imported oil for the region. Thus, total traffic growth for the period is just 4 million tons or less than 3 percent (see Table V-34). The share of hazardous commodities declines sharply during the period, but remains at relatively high levels.

Table V-33

Regional Evaluation Report
Scenario: Baseline
Region: Columbia/Snake-Willamette River

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		26.7	32.3	31.6	31.9	31.5	31.6	32.5
Foreign		16.9	19.6	21.2	21.0	21.8	23.4	26.1
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0080	0.0081	0.0087	0.0092	0.0097	0.0103	0.0107
Increase in Traffic From 1977	million tons	0.0	8.4	9.3	9.4	9.8	11.5	15.0
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	19.0	16.6	16.3	16.4	16.6	15.9	15.2
Average Delay at Locks	hours	0.1	0.1	0.2	0.2	0.2	0.2	0.3

Table V-34

Regional Evaluation Report
Scenario: Baseline
Region: California Coast

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		62.3	92.8	91.5	89.6	87.0	82.0	80.3
Foreign		76.0	42.4	46.2	48.5	53.4	58.7	63.2
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
..gy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0015	0.0015	0.0016	0.0017	0.0017	0.0019	0.0019
Increase in Traffic From 1977	million tons	0.0	-2.9	-0.5	-0.1	2.3	2.5	5.4
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	79.5	75.3	70.8	67.1	63.0	57.3	54.2
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(r) Alaska

Alaskan oil shipments increase sharply from 1977 to a peak around 1985. Thereafter, domestic traffic declines gradually to 82 million tons in 2003 (see Table V-35).

This dramatic increase in traffic coupled with the high traffic share of hazardous commodities may justify the adoption of actions to enhance vessel safety.

Table V-35

Regional Evaluation Report
Scenario: Baseline
Region: Alaska

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		22.2	91.9	95.7	90.8	87.8	83.4	82.3
Foreign		6.6	3.7	3.6	3.6	3.6	3.7	3.8
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/tonmile	0.0011	0.0009	0.0009	0.0010	0.0010	0.0011	0.0011
Increase in Traffic From 1977	million tons	0.0	66.8	70.5	65.5	62.6	58.3	57.3
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	78.8	92.6	92.5	91.5	90.6	89.2	88.5
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(s) Hawaii

Foreign imports of oil decline, but are more than offset by increases in domestic traffic. Overall, traffic increases by 3.2 million tons from 1977 to 2003 (see Table V-36). The reduction in reliance on petroleum results in a reduction in the share of hazardous traffic.

Table V-36

Regional Evaluation Report
Scenario: Baseline
Region: Hawaii and Pacific Territories

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		9.2	10.8	11.8	12.9	14.1	15.6	16.7
Foreign		6.1	5.0	4.9	4.8	4.8	4.7	4.8
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0023	0.0023	0.0024	0.0025	0.0026	0.0028	0.0029
Increase in Traffic From 1977	million tons	0.0	0.5	1.4	2.4	3.6	5.1	6.2
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	59.2	56.0	51.5	47.7	44.4	40.4	38.3
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(t) U.S. Caribbean

Reduced oil imports is expected to reduce total traffic by 15 million tons by 2003. The sharp reduction in imported oil also results in a declining share of hazardous cargoes (see Table V-37).

Table V-37

Regional Evaluation Report
Scenario: Baseline
Region: United States Caribbean

	Unit	1977	1980	1985	1990	1995	2000	2003
Projected Usage	million tons							
Domestic		36.7	38.2	36.7	36.7	37.2	35.2	36.2
Foreign		53.1	54.0	49.3	47.4	44.9	38.8	38.3
Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Energy Traffic vs. Projected Usage	percent							
Domestic		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Foreign		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average Linehaul Costs	$/ton mile	0.0018	0.0019	0.0019	0.0020	0.0021	0.0023	0.0023
Increase in Traffic From 1977	million tons	0.0	2.5	-3.8	-5.6	-7.7	-15.8	-15.3
Average/Maximum Tow Size	percent	NC	NC	NC	NC	NC	NC	NC
Hazardous Commodities	percent	91.3	91.0	89.0	87.5	85.7	82.1	80.8
Average Delay at Locks	hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0

OBSOLETE LOCKS

Another concern about the ability of the waterway system to perform effectively is the physical condition of some of the older locks and the relationship of lock chamber dimensions to traffic characteristics. The main orientation of this evaluation process has been focused upon the end product of water transportation, the movement of commodities. As described in the integration plan, system characteristics per se were not considered to be evaluation measures. Rather performance was defined as the main criterion for evaluation.

Nevertheless locks that can be classified as obselete do affect capability even though they may not physically constrain capacity. Criteria were developed and locks were analyzed against those criteria. This analysis is fully described in Appendix F of this report.

In summary the following locks were found to be obsolete:

1. Lock 1 on the Upper Mississippi River
2. Locks 3, 4, 7, and 8 on the Monongahela River
3. Winfield and Marmet Locks on the Kanawha River
4. Harvey Lock on the Gulf Intracoastal Waterway West.
5. Inner Harbor Navigation Channel Lock on the Gulf Intracoastal Waterway East.
6. Oliver Lock on the Warrior River
7. Bonneville Lock on the Columbia River.

SUMMARY

The findings of the evaluation of the present system relate to:

1. Lock capacity shortfalls.
2. Lock obsolescence.

3. Impacts of such shortfalls on the commercial uses of water transportation.

4. Impacts of such shortfalls on different waterway regions.

5. Possible increases in safety problems as a result of changing traffic conditions.

The findings for each of these categories are discussed below.

(a) Lock Capacity Shortfalls and Lock Obsolescence

Table V-38 presents the list of locks found to be constraining under one or more scenarios or sensitivity analyses. Shortfalls in lock capacity occur in eight regions. Twenty-five separate locations (including five for the Welland Canal locks) have been identified.

Of these twenty-five locations, a small number of locks and dams have been found to be constraining under all four basic scenarios. These locks are:

1. Lock and Dam 26 at the Lower Upper Mississippi.

2. Gallipolis Lock at the Upper Ohio.

3. LaGrange and Marseilles on the Illinois.

4. Demopolis on the Tombigbee.

The single largest shortfall in lock capacity under the four NWS scenarios occurs at Lock and Dam 26.

Under defense emergency the single largest shortfall in lock capacity occurs at the Locks on the St. Mary's River between Lakes Superior and Huron.

Table V-38

NWS Constraining Locks by Scenario and Sensitivity Analysis (1)

		Scenario				Sensitivity Analyses			
						Projected Use			
Region	Lock	Baseline	High Use	Low Use	Bad Energy	Defense	High Coal Exports	Misc. Sensitivities	Lock Capacity
Lower Upper Mississippi	Lock & Dam 26(2)	X	X	X	X		X	X	
Illinois	LaGrange	X	X	X	X		X	X	
	Peoria	X	X		X		X	X	
	Marseilles	X	X	X	X	X(3)	X	X	
Upper Mississippi	Lock & Dam 22	X	X		X		X	X	
Ohio	Gallipolis(2)	X	X	X	X	X	X	X	
	Uniontown		X		X		X	X	
	McAlpine						X	X	
	Newburgh						X		
	Montgomery							X	
	Locks & Dam 52								X
Warrior/Tombigbee	Demopolis(2)	X	X	X	X		X	X	
	Warrior		X				X	X	
	Oliver(4)		X	X	X		X	X	
	Holt		X				X	X	
	Bankhead						X		
	Coffeeville						X		
Great Lakes/Seaway	Welland Canal(2)	X	X		X		X	X	
	St. Mary's River Locks					X(3)			
GIWW East	Inner Harbor(4)						X	X(5)	
Columbia	Bonneville(4)							X	

NOTES: (1) Projected usage reaches or exceeds capacity by 2003.

(2) These are primary constraining locks which, unless expanded, restrict traffic to other locks as well under one or more scenarios.

(3) These are primary constraining locks for the Defense Sensitivity only.

(4) Obsolete locks.

(5) If the traffic forecast at this lock were adjusted for the undercounting of base year traffic, it would constrain traffic under all scenarios.

If the United States were to increase its coal exports greatly, then shortfalls in lock capacity could be expected to take place at multiple locations on the Ohio River and Tombigbee-Warrior System. Three of the four locks are also obsolete.

Table V-39 presents another set of locks. These locks while not constraining, were found to have increases in delay times under one or more scenarios and sensitivity analyses. Accordingly, they represent possible candidates for additional capacity based on detailed project-level analysis of the relative benefits and costs.

Locks which were found to obsolete and either constrain traffic or cause increased congestion are also noted in Table V-38 and V-39. It is interesting to note that six of the eleven locks identified as obsolete also appear in Tables V-38 and V-39.

Table V-39

Other Locks with Increased Congestion
Under One or More Scenarios or Sensitivity Analyses

Region	Lock
Lower Upper Mississippi	Lock and Dam 27
Upper Mississippi	Locks and Dams 15, 16, 17, 18, 19, 20, 21, 24, and 25
Illinois	Starved Rock Dresden Island Lockport
Ohio	Dashields Emsworth
Tennessee	Kentucky
GIWW West	Harvey(1) Algiers

NOTE: (1) Obsolete Locks.

(b) Industry Impacts

There are seven industries that represent the major users of the waterways for transportation. The two industries most directly affected by shortfalls in lock capacity (both as a physical constraint to traffic growth and as an economic constraint as measured by increases in line-haul costs due to increases in lock delays) are the agriculture and the coal industries. These two industries account for over two-thirds of the tonnage that cannot be accommodated by the present system under any of the four NWS scenarios (see Table V-40).

Table V-40

Projected Use Not Accommodated in 2003 Due to Shortfalls in Lock Capacity by Industry
(Millions of Tons)

Industry	Baseline	High Use	Low Use	Bad Energy
Agriculture	16.0	19.5	8.0	25.0
Fertilizer/Chemicals	3.6	4.9	1.9	4.4
Steel	3.6	8.3	0.7	8.5
Coal	9.1	23.3	2.8	15.4
Petroleum	2.3	3.0	1.1	2.4
Forest Products	0.1	0.1	0.0	0.2
Other	1.7	2.6	0.8	2.4
TOTAL	36.4	61.7	15.3	58.3

The steel industry is also adversely affected by shortfalls in lock capacity under two of the four scenarios. However, the fertilizer/chemicals industry, the petroleum industry, and the forest products industry are expected to be well served by the present system.

This same pattern of industry impacts applies to trends in the line-haul costs of domestic marine shipments as well. The largest percentage increases in ton-mile costs from 1977 to 2003 occur for the agriculture and coal industries (see Table V-41).

Table V-41

Increase in Linehaul Costs
for Domestic Marine Shipments
(Mills Per Ton-Mile in 1977 Dollars)

		2003				
Industry	1977	Baseline	High Use	Low Use	Bad Energy	Percent Change
Agriculture	4.3	6.8	6.8	6.6	6.8	58%
Fertilizer/Chemicals	7.4	10.6	10.6	10.6	10.7	43
Steel	3.5	4.7	5.0	4.9	4.9	40
Coal	4.8	7.3	7.3	7.2	7.4	52
Petroleum	4.9	6.3	6.3	6.7	6.7	33
Forest Products	4.2	5.9	5.9	5.9	5.9	40
Other	11.7	15.0	15.3	15.4	15.5	31
All Traffic	5.9	8.0	8.0	8.2	8.3	38

(c) Regional Impacts

The regional impacts of lock capacity shortfalls are shown in Table V-42. As can be seen, the greatest amount of projected usage (as measures in millions of short tons) cannot be accommodated in the four Mississippi River Regions, reflecting the "systemwide" effects of a shortfall in capacity at Lock and Dam 26.

The Illinois, Ohio, and Great Lakes/Seaway regions are not able to accommodate projected usage under at least three of the four NWS scenarios as well.

(d) Regions with Potential Safety Safety Problems

The evaluation of the present system has included an analysis of water transportation safety problems. Section IV presented a list of over 200 sites that historically have posed safety problems. Actions in the four NWS strategies have been designed to address these problems. The analysis in this section identifies those regions where significant safety problems may occur in the future due to changing traffic conditions.

Table V-42

Projected Use Not Accommodated in 2003 Due to Shortfalls in Lock Capacity in Region
(Millions of Tons)

Region	Baseline	High Use	Low Use	Bad Energy	High Coal Exports	Other Adjustments
Upper Mississippi	11	11	6	14	11	11
Lower Upper Mississippi	24	25	14	31	25	25
Lower Mississippi	20	23	11	29	27	30
Baton Rouge to Gulf	20	23	11	28	27	29
Illinois Waterway	13	15	7	18	15	15
Ohio	9	21	2	13	32	65
Tennessee	1	9	1	2	18	12
Arkansas	0	0	0	0	0	1
Gulf Coast West	2	4	1	3	5	7
Gulf Coast East	-	6	1	1	10	6
Mobile River and Tributaries	-	8	1	1	16	9
Great Lakes/Seaway	5	15	-	17	16	15
Columbia/Snake	0	0	0	0	0	6
Eliminate Interregional Double Counting	(69)	(97)	(39)	(99)	(125)	(125)
TOTAL	36	63	16	58	77	106

Table V-43 presents regions where there is potential for increases in safety problems. Without offsetting actions, a deterioration in safety performance due to changes in traffic can be expected in these regions.

Table V-43

Regions With Potential Safety Problems
(Baseline Scenario in 2003)

	Increase from 1977 in Traffic (Millions of Tons)	Average Lock Delay (Hours)	Average to Maximum Tow Size (%)	Share of Hazardous Commodities %
Upper Mississippi	24	21.7	64	13
Lower Upper Mississippi	60	3.9	39	17
Baton Rouge to Gulf	167	--	33	35
Illinois Waterway	30	8.4	43	16
Ohio	129	4.9	63	14
Tennessee	37	1.5	49	15
Gulf Coast West	42	0.2	55	65
Gulf Coast East	43	0.4	60	34
Mobile River and Tributaries	75	3.5	100	16
Great Lakes/Seaway	191	6.8	--	3
Washington-Oregon Coast	53	--	--	51
Alaska	57	--	--	89

The Upper Mississippi, Ohio, and Tennessee River Regions as well as the Mobile River and Tributaries Region have common changes in traffic conditions that can lead to increases in safety problems.

1. Sharply higher traffic growth.

2. Increased tow delays at locks.

3. Relatively high average to maximum tow size ratios.

The Lower Upper Mississippi and Illinois Waterway Regions also have higher traffic and increased tow delays, although the issue of changes in tow maneuverability as a result of changes in average tow size and channel configurations is not as much of a problem.

The Great Lakes/St. Lawrence Seaway can expect to have safety problems arising from the sharp increase in traffic and substantial increase in vessel delays at the Welland Canal, and the St. Mary's River.

Five coastal areas (three Gulf Coast areas, one West Coast area and Alaska) can expect to have significant safety problems with the sharp increase in traffic levels and the relatively high levels of hazardous cargoes that pose environmental problems as well as human safety problems.

VI - CONCLUSIONS

This section summarizes eight conclusions regarding the performance of the present waterways system, based on the discussion in Section V. It should be emphasized that these conclusions are valid only for the time horizon of the National Waterways Study which is a fairly short (25 year) horizon for a Corps study. The conclusions are stated below.

1. Assuming that the present waterways system is properly operated, maintained, and rehabilitated throughout the study period, the present waterways system performs relatively well in terms of accommodating current and projected waterborne commodity flows through the year 2003 under most forecasts.

2. Not all flows can be accommodated by the present system. In particular, almost six percent of projected domestic waterborne flows (or approximately 89 million tons) and over one percent of projected foreign waterborne flows (or 17 million tons) cannot be accommodated due to lock capacity shortfalls under the worst case forecast for the future.

3. These lock capacity shortfalls are not simply concerns of local interests. Rather, a few capacity short-falls (namely Lock and Dam 26 on the Lower Upper Mississippi, the Welland Canal Locks on the St. Lawrence Seaway, Gallipolis and Uniontown on the Ohio River) have national impacts in that they affect entire industries and multiple regions.

4. These lock capacity shortfalls are likely to disrupt the logistics systems of the agriculture and coal industries more so than any other industry.

5. While the present system does a reasonable job of accommodating current and projected waterborne flows, it does so at higher real costs to water transportation users and with increased safety problems. The agriculture and coal industries experience the faster rate of growth in the line-haul costs of domestic marine shipments. There are over 200 sites that historically have posed one or more safety problems. Changes in

traffic conditions can be expected to increase the future potential for safety problems in at least 10 of the 22 waterway regions.

6. With regard to national defense, there is a clear priority for further study and action to address the need[1] for additional lock capacity at the St. Mary's River between Lakes Superior and Huron. The ability of the United States to increase its steel-making capability under a major military emergency would be limited by the present lock chamber facilities at this site.

Other locks were also found to constrain traffic under a defense emergency, but the magnitude of the impact is less and these locks also are constraints to normal flows under one or more scenarios.

7. Errors in traffic reporting at locks, when corrected, also result in additional locks being found to be constraints. The Inner Harbor Navigation Canal Lock in New Orleans in particular would constrain under all scenarios if the under-reporting were corrected.

8. With regard to this nation's desire to promote exports of grain and coal, there are clear priorities for further study and action. These priorities include the need for a second chamber at Lock and Dam 26,[1] additional capacity at the Canadian owned and operated Welland Canal locks of the St. Lawrence Seaway, and several other locks on the Ohio River System and the Tombigbee-Warrior system.

9. Some locks of the present system are also obsolete and these pose problems for the system. While some obsolete locks are also constraints, the strictly defined list of obsolete locks does not include the major primary constraints noted in paragraph 3 above.

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1 The use of the word "need" is not meant to suggest that such a change to the present system's configuration is required at any cost. Numerous actions of differing costs can be taken. Furthermore, as is true of all investment decisions, the decision on whether to invest is distinct from the decision on how to finance.

GLOSSARY OF TERMS

Action: An NWS action is a discrete construction activity; change in level of operations, maintenance, and rehabilitation activity; change in lock operating policy; or change in level of traffic management.

Approach: Travel of a tow from the approach point, or from a point on the lock guidewall clear of the lock gates in the case of a turnback approach, to a point where the bow of the tow is abreast of the lock gates and the tow is parallel to the guidewall ready to enter the lock chamber.

Approach Point: The closest point to a lock at which one tow can safely pass another tow traveling in the opposite direction. Tows may not normally proceed beyond the designated approach point of a lock without the permission of the lockmaster.

Approach Speed: Rate of movement of two during approach.

Approach Time: Time passed by the two in the approach as above.

Auxiliary Chamber: A chamber of a multiple-chamber lock which is usually smaller and used less than the main chamber. Auxiliary chambers are normally used to pass small tows, light boats, and recreational vessels, and to maintain navigation during periods when the main chamber is shut down.

Backhaul: The movement of barges or vessels on a return trip from destination to origin for another load. Backhaul trips can be empty or loaded with a different cargo for at least part of the trip.

Barge: A non-self-propelled, usually flat-bottomed vessel, used for carrying freight on inland waterways.

Beam: The width of a vessel at its widest point.

Capability: For NWS, water transportation capability is the ability of the present navigation system to handle commercial navigation safely and at a line-haul cost consistent with the historical cost relationship among the transportation modes.

Capacity: The ability of a lock or channel to handle commercial navigation measured in tons during a year.

Chamber: The part of a lock enclosed by the walls, floor, sills, and gates; the part of a lock within which the water level is changed as vessels are raised or lowered. A lock may have more than one chamber, and they may be adjacent or laterally separated.

Chambering: That part of a lockage cycle starting at the end of the entry and ending when the exit gates are fully recessed, or when the bow of the exiting vessel crosses the lock sill, whichever is earlier. Chambering includes closing the entry gates, filling or emptying the lock chamber, and opening the exit gates.

Chambering Time: The time it takes to close the entry gates, fill or empty the chamber and open the exit games.

Channel Maintenance: Dredging, lighting and other operations which assure or maintain the navigability of a channel.

Cut: A segment of a tow which is put through a lock separately from other segments of the tow.

Double Lockage: The type of lockage performed when a tow passed through a lock chamber in two segments or "cuts."

Entry: That part of a lockage cycle starting at the end of the approach and ending when the tow or cut is secured within the chamber and the gates are clear, or when the closing of the gates has been initiated, whichever is earlier.

Entry Time: The time taken from the end of approach (when the bow is over the sill) until the tow is secured in the chamber.

Exchange Approach: The type of approach executed when the vessel inbound to the chamber passes a vessel outbound from the chamber.

Exchange Exit: The type of exit executed when the vessel outbound from the chamber passes a vessel inbound to the chamber.

Exit: That part of a lockage cycle starting at the end of chambering and ending when the lock has completed service a vessel or cut and can be dedicated to another vessel or cut.

Exit Time: The time between the end of the chambering operation and when the tow is clear of the lock.

First Come - First Served: A lock operating policy in which vessels are selected for service in the order in which they arrived at the lock, irrespective of travel direction; often abbreviated FCFS.

Fly Approach: The type of approach executed when the lock has been idle and the inbound vessel proceeds directly to the chamber.

Fly Exit: The type of exit executed when the lock will be idle following the departure of the outbound vessel, that is, when no vessels are awaiting lockage.

Integration: The NWS study process of evaluation of the present navigation system, and application and evaluation of strategies.

Intracoastal Waterway: Inland route paralleling the coast for inland craft.

Jacknife Lockage: A type of lockage in which the tow is rearranged, usually from two barges wide to three, by breaking the face coupling on at least one barge and knockout of the towboat.

Jumbo Barge: A barge 195 feet long and 35 feet wide.

Knockout Lockage: A type of lockage in which the towboat alone is separated from its barges and set alongside of them in the lock chamber.

Lock: A structure on a waterway equipped with gates so that the level of the water can be changed to raise or lower vessels from one level to another.

Lockage: Passage of a tow or other vessel through a lock. A normal lockage cycle consists of an approach, entry, chambering, and exit.

Lockage Time: The time elapsed from the start of approach of the first vessel or cut served by a lockage to the end of exit of the last vessel or cut served by a lockage. Includes the time required to disassemble and assemble multiple-cut tows and to rearrange setover tows, when such activities prevent the use of the lock by other vessels.

Multiple-Cut Lockage: The type of lockage performed when a tow must be passed through the lock in two or more segments or "cuts".

Multiple-Vessel Lockage: A type of lockage in which more than one vessel or tow is served in a single lockage cycle.

Navigable Dam: A navigation dam which permits the passage of vessels without the use of a lock during periods of high water.

Navigable Pass: An operation whereby a vessel traverses a navigable dam without passing through a lock.

Navigation Season: That part of the year when the waterway is open to traffic.

N up/M down: A lock operating policy in which up to N upbound vessels are serviced, followed by up to M downbound vessels, where N and M are positive integers.

N up/N down: A commonly used special case of N-up/M-down, in which N and M are equal.

Non-Structural Measure: Proposed measure to improve navigation on a waterway or segment not involving building of a lock nor any structural modifications to the lock or waterway.

O & M: Operation and Maintenance.

One Way Reach: A reach narrow enough that two vessels may not pass simultaneously.

Open Pass: Passage of a vessel through a lock with no lock hardware operation. This is possible only when the upper and lower pool levels are nearly equal, and occurs most frequently at tidal locks.

PMS: Performance Monitoring System. The Corps of Engineers system for keeping and producing statistics at locks. It is not applied uniformly at all locks.

Practical Lock Capacity: For NWS integration purposes, practical lock capacity is defined as 90% of theoretical capacity.

Projected Use: A forecast of waterborne commodity flows that can be expected to use water transportation without regard to constraints.

Recreational Lockage: A lockage of recreational craft.

Reach: A channel segment between two given points on a waterway.

Representative Lock: A lock designated as representative of locks of similar size.

Reliability: Refers to the percentage of time a facility is in use or able to be used.

River Mile: A number specifying the location of a point along a waterway, obtained as the distance from a reference point designated as mile zero.

Scenario: Assumptions about uncontrollable events affecting the use or performance of the navigation system.

Setover Lockage: A lockage in which the towboat and one or more barges are separated as a unit from the remaining barges and set alongside of them in the lock chamber. The term is usually applied only to single lockages, but is could be used to describe any cut. The term is often used to refer to all types of single lockages requiring rearrangement of the tow.

Sill: A transverse structural element of a lock chamber upon which the lockgates res t when they are closed; the upstream or downstream boundary of a lock chamber.

Single Lockage: The type of lockage performed when the entire tow can fit into the lock chamber, with or without rearrangement, and hence requiring only one lock operating cycle.

Standard Barge: A barge 175 feet long and 26 feet wide.

Straight Lockage: A lockage which does not require rearrangement of the tow in order for the two to fit into the lock chamber. The term is usually applied only to single lockages, but it could be used to describe any cut.

Strategy: A set of policies and directives for taking actions to meet water transportation needs.

Switchboat: A towboat used to assist tows requiring a multiple-cut lockage. A switchboat may be used to assist a tow entering or exiting the lock chamber, or it may independently power a cut through the lock.

Ton: A unit of weight equal to 2,000 pounds avoirdupuis (907.20 kilograms); short ton.

Ton-Mile: A unit of transportation production equal to the movement of one ton a distance of one statute mile.

Tow: A towboat and one or more barges which are temporarily fastened together and operated as a single unit.

Towboat: A shallow-draft commercial vessel used to push or pull barges.

Tow Configuration: Orientation of barges tied together to form a tow.

Traffic: As used in the evaluation of the present system and strategies in NWS, traffic refers to tons of projected use actually accommodated.

Turnback: A lockage in which no vessels are served; a reversal of water level in a lock chamber with no vessels in the chamber. A turnback includes closing one set of gates, filling or emptying the chamber, and opening the other set of gates. Also called a "swingaround" or an "empty lockage."

Turnback Approach: The type of approach executed when the preceding event at the lock was a chamber turnback.

Turnback Exit: The type of exit executed when the next event is a lockage in the same direction, requiring a chamber turnback.

APPENDIX A

NWS FORECASTS OF UNCONSTRAINED WATERBORNE COMMODITY FLOWS BY REPORTING REGIONS AND COMMODITY GROUP

This Appendix to the Element K2 (Evaluation of the Present Navigation System) report is published under separate cover. These forecasts were completed by Data Resources Inc. in conjunction with A. T. Kearney Inc. under Element B (Traffic Forecasting Methodology).

APPENDIX B

LINKAGE BETWEEN ELEMENT K1 (ENGINEERING ANALYSIS OF WATERWAYS SYSTEMS) AND K2 (EVALUATION OF THE PRESENT NAVIGATION SYSTEM) AND L (EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION) WORK

APPENDIX B

This appendix outlines the relationship between the lock capacity analysis performed in Element K1 (Engineering Analysis of Waterways Systems) and the subsequent lock capacity analysis conducted during integration.

ELEMENT K1 (ENGINEERING ANALYSIS OF WATERWAYS SYSTEMS)

According to the study workplan, Element K1 had the following major tasks:

1. Development of a methodology for assessing lock capacity.

2. Development and costing of possible actions to increase the capacity of potential congested locks.

3. Development of a methodology relating maintenance of channel dimensions to dredging volume.

4. Development of a methodology relating reliability of channel dimensions to hydrological conditions and available water flow.

5. Development of a methodolgoy for estimating transit time, after taking into account channel curvature, inadequate bridge dimensions, shallow water, lock delays and other restrictions.

6. Development of costs for all other actions to maintain or improve the waterways.

7. Development of a methodology to estimate the costs of line-haul operations for waterborne movements.

With regard to the lock capacity analysis, Element K1 did provide a methodology for calculating lock capacity and this methodology was adopted in the subsequent K2/L

analysis. The only modifications made in K2/L to the basic equations are as follows:

1. An adjustment was made to eliminate the loss in chambering time due to the make-up and break-up of tows.

2. An adjustment was made to eliminate the loss in chamber availability due to recreational craft.

3. An adjustment was made to incorporate a 4-up/4-down lock operating policy where an examination of times for fly/exchange and turnback lockages indicated that savings were possible.

4. Adjustments were made for the numerous exceptions to any general rule including:

(a) Triple lockages.

(b) Multi-vessel lockages.

(c) Open-pass conditions.

In addition, the integration analysis had to project lock capacity through the year 2003. Element K1 (Engineering Analysis of Waterways Systems) recognized that average tow size, average barge ladings, and percent loaded at locks would vary with changes in the mix of traffic at these locks, but, for its analysis, no adjustments were made to the base-year data. Element K2/L developed the methodology for projecting these changes based on changes in the underlying commodity flow data.

In addition to developing an equation for estimating lock capacity, Element K1 calculated the costs for actions to increase lock capacity. In order to spend limited resources most effectively, Element K1 focused its resources on representative locks that might be considered potentially constraining at the present time or in the future. Potentially constraining locks were identified by looking at reported delay times in 1976 as well as 1976 chamber utilization as indicated by 1976 traffic level and capacity estimates based on present lock operating conditions (generally no non-structural actions). Every

attempt was made to be inclusive so that all possible lock capacity actions taken in the K2/L strategies would be costed.

ELEMENT K2/L

Element K2/L had as its primary objectives:

1. The evaluation of the present system in order to identify water transportation needs (Element K2).

2. The formulation and evaluation of alternative strategies for action to meet needs (Element L).

Accordingly, water transportation needs (i.e., changes in the present system required to handle current and projected waterborne commodity flows safely and at a line-haul cost consistent with the historical cost relationship among modes) for lock capacity were identified in Element K2 (Evaluation of the Present Navigation System) using:

1. The modified K1 equations for estimating lock capacity.

2. Projected changes in average barge or vessel barging, average tow size, and percent loaded at individual locks caused by changes in traffic mix through 2003.

3. Forecasts of traffic at individual locks for seven time periods, four scenarios, and three sensitivity analyses.

The analysis presented in Element K2 (Evaluation of the Present Navigation System) involved comparing forecasts that have been consistently developed from logical sets of assumptions about the national economy and major industries with estimates of lock capacity that have been developed consistently using two generalized equations for all commercially important locks, taking into account the systematic interaction of traffic between locks.

The analysis was deliberately designed to identify those lock chambers where a physical shortfall in capacity could be expected to take place by the year 2003. It should be noted that, as a practical matter, some additional locks with sharp increases in delay might be candidates for replacement based on detailed benefit-cost analyses that deliberately take into account the benefits accruing to new construction from reductions in tow and vessel delays.

APPENDIX C

LOCK CAPACITY METHODOLOGY AND DATA

APPENDIX C

LOCK CAPACITY METHODOLOGY AND DATA

This appendix presents the equations and underlying data for the NWS lock capacity analysis conducted in the K2 phase of the integration process.

Before discussing the equations, it should be noted that a "respresentative concept" was adopted from work under prior Element K1 (Engineering Analysis of Waterways Systems) for selected lock chambers. The concept is based on the conclusion that the capacity of chambers with similar or identical characteristics and of close proximity can be calculated from the data for one of these chambers. For Element K2 (Evaluation of the Present Navigation System), this concept was adopted only for those chambers where capacity exceeded projected traffic under all scenarios by a substantial margin. Wherever possible, attempts were made to incorporate data specific to each chamber. In the case of tow sizes, unique values were used for most locks.

It also should be noted that the data used for most of the analysis are the data that were provided to the contractor team by the Corps very early in the NWS. The lock capacity conclusions stated by the contractor team in the public meetings of November 1980 are based on these data. Every effort has been made to reconcile any known differences in the K2 capacity calculations and underlying data with other calculations and data presented in other reports. It is assumed that all problems and discrepancies have been discovered and resolved.

One final point should be made about the selection of locks for capacity analysis. Locks were included in the calculations if two conditions were met. These were: 1) the availability of data with which to estimate capacity and 2) the significance of commercial traffic. For example all the locks on the Fox River in Wisconsin have had no commercial traffic in several years and were excluded. Other locks which pass some tonnage were

excluded because no data were available even though such locks had some traffic. For example, the Dismal Swamp Canal Route in Virginia, an alternative routing for part of the Atlantic Intracoastal Waterway, reported a total of 160,300 tons of traffic in 1977. Even if it is assumed that all traffic on this route passed through South Mills Lock, the only lock on the canal, it is highly unlikely that this lock will ever approach a constraining condition during the study period. On the other hand, some locks were included which do not pass the "commercial significance" test (e.g., Locks 5 through 14 on the Kentucky), solely because representative data were available.

The basic lock capacity model is taken from prior Element K1 work. A major finding from the Element K1 work is that projections using a more sophistocated lock capacity estimation procedure entitled LOCKAP do not produce signficantly different capacity estimates than the simple model used in the Element K1 lock capacity analysis. The Element K2 lock capacity analysis used a variation of the K1 equations. The Element K2 equations are:[1]

C-1. $P_D = a + bS$

C-2. $T = (Z_1 - \frac{3}{4}H_1) + P_D Z_2$

C-3. $C = 473{,}040 \times (1/T) \times L \times S \times K_1 \times K_2 \times K_3$

a	--	Intercept of tow size-percent double equation
b	--	Slope of tow size-percent double equation
Z_1	--	Cycle time for fly exchange lockage ($Z_1 = A_F + E + F + X_F$)
Z_2	--	Time for turnback lockage ($Z_2 = A_T + E + X_T + 2F$)

1 The constant term 473,040 in equation C-2 is 90% of the minutes in a 365 day year of 24 hour days. The equation result is an estimate of practical capacity, defined for NWS as 90% of technical capacity. See Element K1 (Engineering Analysis of Waterways Systems).

H_1	--	The savings from N up/N down ($H_1 = A_F + X_F - A_T - X_T - F$)
T	--	Average processing time by chamber
P_D	--	Percent of double lockages
A_F	--	Fly exchange approach time
E	--	Entry time
F	--	Chamber time
X_F	--	Fly exchange exit time
A_T	--	Turnback approach time
X_T	--	Turnback exit time
L	--	Average lading
S	--	Average tow size
K_1	--	Percent loaded barges
K_2	--	Coefficent for frequency of chamber availability during open season, length of season, and monthly seasonality of traffic passing the lock chamber.
K_3	--	Chamber interference parameter.

The original equation developed in Element K1 (Engineering Analysis of Waterways Systems) was modified to make it applicable to the broad range of operating conditions that one finds not only in the river segments, but also in the coastal and Great Lakes segments. This required making adjustments for open pass conditions, triple lockages, and multi-vessel lockages.

The orignal equation in Element K1 (Engineering Analysis of Waterways Systems) was also modified to incorporate the effects on capacity of the following non-structural actions:

1. Use of a 4-up and 4-down lock operating policy where appropriate.

2. Elimination of possible conflicts between recreational and commercial use of the chambers.

3. Elimination of any chamber time lost for the making and breaking of tows in or around the lock chamber.

The effects of these actions were incorporated into the basic lock capacity model, because it was assumed that

such low capital-cost actions would be adopted very quickly under conditions of lock congestion.

Using the above equations and the data contained in Table C-2, it was possible to calculate lock capacity for 1977. For all lock capacity analysis for succeeding years, it was necessary to modify the base 1977 data in a logical manner to reflect changes in the mix of commodity flows at locks from 1977 to 2003.

The capacity calculation sequence treated the three equations as three distinct steps. The three steps were as follows:

1. Project the percentage of double lockages based on changes in tow size using equation C-1.

2. Calculate the projected service time using equation C-2.

3. Calculate tonnage throughput capacity using equation C-3 and the service time calculated in equation C-2.

The average tow size estimate at each lock for 1977 was adjusted for all subsequent years by estimating the change in the weighted-average tow size for all traffic passing the lock. In order to accomplish this step, it was necessary to assign segment-specific tow sizes for different types of commodities and then develop a weighted-average tow size for each time period based on the projections of traffic passing each lock.

One key finding in the Element K1 work was that the percent of double lockages could be predicted with good reliability based on average tow size. Larger average tow sizes passing through a lock will generate additional double lockages. Nomographs were developed to facilitate the estimation of the percent of double lockages. These nomographs were in turn expressed as simple linear equations for each chamber (equation C-1). The values of

the slope and intercept of each equation are shown in Table C-2.[2]

Equation C-1 was the first equation solved by the program. The result was constrained to be greater than or equal to zero and less than or equal to one. The result was then used in equation C-2.

The average lading overtime at locks was also projected. The technique was similar to that used for projecting two sizes. Segment specific ladings for different commodities were assigned and changes in weighted averages applied to the base year 1977 data. Ladings at the Great Lakes-St. Lawrence Seaway Locks were handled somewhat differently. Trends in average ladings were examined (where available) and simple linear forecasts in ladings were extrapolated for these locks.

Changes in the percentage of empty barges or vessels passing locks were also projected to the year 2003 using segment traffic data. Each analytical commodity was estimated to be either susceptible to backhaul movements or not. For susceptible commodities within each segment, the change in the ratio of upbound to downbound flows was computed. For commodities that were not considered to be susceptible, it was assumed that they are 100 percent empty backhaul movements. A change in the overall empty ratio was computed for each segment over time and was used to adjust the base year data.

Open pass conditions exist when the pool elevations on both sides of a chamber are the same or differ insignificantly. All locks where this occurs are part of the shallow draft system. Some of these locks are salt water intrusion control devices found on the Gulf Coast on the Gulf Intracoastal Waterway. When these locks are operated as open passes, both the upstream and downstream mitre gates are opened and tows pass directly through the chambers. Locks which experience open pass conditions are

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2 For a full discussion see Section III of the Element K1 Report (Engineering Analysis of Waterways Systems).

also found on the Ohio and Illinois Rivers. In these cases, when pool differentials become minimal, sections of the dams are lowered and tows pass through the dams bypassing the lock chambers altogether.

A complete analysis of locks with open pass conditions during part of the year should be based upon a detailed study of seasonal variations in traffic and their relationships to seasonal variations in passage conditions. However, this was viewed as too detailed for NWS and the rule was adopted that if open pass conditions existed 60 percent of the time, then the lock would be classified as non-constraining. The rationale behind this was that the probability of extreme traffic peaks coinciding with nonopen pass conditions would be low. All locks subjected to analysis which experience open pass are further footnoted in the text.

The other major lock capacity analytical problem which necessitated the development of additional data and the modification of the methodology was the treatment of "multivessel lockages". Multivessel lockages are lockages where more than one tow is locked simultaneously thorugh in a single lock operation. This is an uncommon type of lockage. The conditions required for these lockages to occur are a high level of traffic moving in small tows combined with fairly large lock chambers. When these conditions are combined, multi-vessel lockages are feasible because the area of the chamber permits them and the frequency of tow arrivals is high enough to create a queue that can be effectively served in this manner. Double lockages are infrequent or nonexistent under these conditions.

These conditions already exist at several locks in Louisiana and/or are expected to become more significant in the future. A separate equation was devised as part of Element K2 (Evaluation of the Present Navigation System) to calculate service times under these conditions. The equation used is shown below:

C-4. $T = (Z_1 - \frac{3}{4}H_1) + P_D Z_2 + P_M \left[\left(\frac{1}{M} - 1\right)\left(Z_1 - \frac{3}{4}H_1\right) + \frac{M-1}{M} Z_5 \right]$

The additional variables in this equation are:

Pm -- Percent of multivessel lockages

M -- Number of tows in a multivessel lockage

Z_5 -- Extra time per additional tow in a multivessel lockage ($Z_5 = A_T + X_T + E$)

The two additional variables of most interest in this equation are the percent of multivessel lockages (Pm) and the number of tows in a multivessel lockage (M). The equation also incorporates the nonstructural measures discussed earlier in this appendix.

For all locks analyzed the number of tows established for an N up/N down policy was set at four (N=4). (It should be noted that if the savings from an N up/down policy are zero or negative then the value for savings is set at zero ($H_1 = 0$)). It is recognized that 4 up/4 down may not be the policy which maximizes capacity for all sites. However, it probably captures a high percentage of the effects of local variants of this type of policy. Also, it was not possible, at the NWS level of abstraction to analyze this lockage policy at the level of detail that would be employed by an implementing field office.

The basic lock service time equation described earlier also included a variable for the percent of double lockages (P_d), which in turn varied with average tow size. Thus for all other locks where double lockages occurred the service time itself would vary over time. In the case of locks with multivessel lockages a simpler approach was taken and both P_d and P_m were assigned values that did not vary over time. The result was that average service times for these locks were held constant over the service period. The values assigned are shown in Table C-1 below.

The remainder of this appendix (Table C-2) contains data developed in a standard format for all locks evaluated.

Table C-1

Key Values for Locks With Multivessel Lockages

Lock Name	P_u	P_m
Inner Harbor	6%	35%
Calcasieu	0	10
Vermilion	0	32
Algiers	10	50
Harvey	17	40
Port Allen	0	6

Table C-2

Data for Lock Capacity Analysis

(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Vessel or Tow Size	Average Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight[3]	Lock Cycle Times (minutes) Turnback[4]
Upper Mississippi	Upper Mississippi	Mississippi R., Minneapolis to mouth of Illinois R.	L&D 25	241	600	110	10	1939	8.9	1,475	68%	73%	35	31
			L&D 24	273	600	110	10	1940	8.9	1,475	68	73	35	31
			L&D 22	301	600	110	11	1938	9.2	1,478	68	73	54	37
			L&D 21	325	600	110	11	1938	9.1	1,478	68	73	35	31
			L&D 20	343	600	110	10	1936	9.1	1,475	68	73	35	31
			L&D 19	364	1,200	110	38	1957	8.8	1,479	68	71	60	68
			L&D 18	411	600	110	10	1937	8.3	1,475	68	73	35	31
			L&D 17	437	600	110	8	1939	8.1	1,475	68	73	35	31
			L&D 16	457	600	110	9	1937	7.4	1,475	68	73	35	31
			L&D 15	483	600	110	16	1934	7.6	1,495	71	70	37	40
			L&D 15	483	360	110	16	1934	1.5	1,494	33	70	25	38
			L&D 14	493	600	110	11	1939	7.6	1,495	71	70	37	40
			L&D 14	493	320	80	11	1922	1.5	1,494	33	70	25	38
			L&D 13	523	600	110	11	1939	8.8	1,421	67	64	31	30
			L&D 12	557	600	110	9	1939	8.8	1,421	67	64	31	30
			L&D 11	583	600	110	11	1937	8.4	1,421	67	64	31	30
			L&D 10	615	600	110	8	1936	8.3	1,421	67	64	31	30
			L&D 9	648	600	110	9	1938	8.5	1,421	67	64	31	30
			L&D 8	671	600	110	11	1937	8.4	1,421	67	64	31	30
			L&D 7	703	600	110	8	1937	8.3	1,421	67	64	31	30
			L&D 6	714	600	110	7	1936	8.3	1,421	67	64	31	30
			L&D 5A	729	600	110	6	1936	8.1	1,421	67	64	31	30
			L&D 5	738	600	110	9	1935	8.1	1,421	67	64	31	30
			L&D 4	753	600	110	7	1935	8.1	1,421	67	64	31	30
			L&D 3	797	600	110	8	1938	7.7	1,421	67	64	31	30
			L&D 2	815	600	110	12	1930	7.0	1,488	60	59	32	40
			L&D 1	848	400	56	38	1948	1.8	1,271	50	51	28	41
			L&D 1	848	400	56	38	1932	1.8	1,271	50	51	28	41
			Lower St. Anthony	853	400	56	25	1940	1.8	1,271	50	51	28	41

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Width (feet)	Lift (feet)	Double Lockage Variables Intercept	Slope	Interference Parameter[5]
Upper	Upper	Mississippi R.,	L&D 25	241	600	110	10	-0.43	0.12	1.00
Mississippi	Mississippi	Minneapolis to	L&D 24	273	600	110	10	-0.43	0.12	1.00
		mouth of	L&D 22	301	600	110	11	-0.43	0.12	1.00
		Illinois R.	L&D 21	325	600	110	11	-0.43	0.12	1.00
			L&D 20	343	600	110	10	-0.43	0.12	1.00
			L&D 19	364	1,200	110	38	0.00[6]	0.00[6]	1.00
			L&D 18	411	600	110	10	-0.43	0.12	1.00
			L&D 17	437	600	110	8	-0.43	0.12	1.00
			L&D 16	457	600	110	9	-0.43	0.12	1.00
			L&D 15	483	600	110	16	-0.43	0.12	1.00
			L&D 1[illegible]	483	360	110	16	-0.54	0.28	1.00
			[illegible] 14	493	600	110	11	-0.43	0.12	1.00
			[illegible] 14	493	320	80	11	-0.54	0.28	1.00
			[illegible]	523	600	110	11	-0.43	0.12	1.00
			L&D 12	557	600	110	9	-0.43	0.12	1.00
			L&D 11	583	600	110	11	-0.43	0.12	1.00
			L&D 10	615	600	110	8	-0.43	0.12	1.00
			L&D 9	648	600	110	9	-0.43	0.12	1.00
			L&D 8	671	600	110	11	-0.43	0.12	1.00
			L&D 7	703	600	110	8	-0.43	0.12	1.00
			L&D 6	714	600	110	7	-0.43	0.12	1.00
			L&D 5A	729	600	110	6	-0.43	0.12	1.00
			L&D 5	738	600	110	9	-0.43	0.12	1.00
			L&D 4	753	600	110	7	-0.43	0.12	1.00
			L&D 3	797	600	110	8	-0.43	0.12	1.00
			L&D 2	815	600	110	12	-0.43	0.12	1.00
			L&D 1	848	400	56	38	-0.54	0.28	1.00
			L&D 1	848	400	56	38	-0.54	0.28	1.00
			Lower St. Anthony	853	400	56	25	-0.54	0.28	1.00

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Vessel or Tow Size	Average Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight[3]	Lock Cycle Times (minutes) Turnback[4]
Lower Upper Mississippi	Lower Upper Mississippi	Mississippi R., Illinois R. to Missouri R.	L&D 26	203	600	110	15	1938	10.4	1,457	65%	89%	51	45
			L&D 26	203	360	110	15	1938	3.5	1,578	52	89	40	42
	Middle Mississippi	Mississippi R., Missouri R. to Ohio R. (Chain of Rocks Canal)	L&D 27	185	1,200	110	13	1963	7.8	1,513	66	93	43	44
			L&D 27	185	600	110	13	1963	7.3	1,480	62	93	33	31
Baton Rouge to Gulf	Ouachita, Black, Red	Black R.	Jonesville	25	600	84	30	1972	6.0	1,945	50	89	30	38
		Ouachita R.	Columbia	117	600	84	18	1972	2.3	1,945	54	86	37	42
			L&D 6	223	268	55	10	1923	4.7	909	51	86	26	31
			L&D 8	283	268	55	14	1926	4.7	909	51	86	26	31
		Red R., mouth to Shreveport	L&D 1[7]	NA	685	84		1983	3.7	1,381	41	70	31	43
	Old and Atchafalaya	Old R.	Old River	304	1,200	75	32	1963	2.5	1,851	71	90	29	28
	Baton Rouge - Morgan City Bypass	Port Allen Route	Port Allen	228	1,198	84	45	1961	2.4	1,850	71	90	51	57
			Bayou Sorrel	37	800	75	21	1952	NA	NA	NA	op[8]	NA	NA
		Bayou Teche	Berwick	116	307	45	11	1951	4.7	909	51	op[9]	26	31
Illinois Waterway	Illinois Waterway	Illinois R.	LaGrang	80	600	110	10	1939	8.0	1,532	61	81[10]	38	44
			Peoria	158	600	110	11	1939	6.9	1,532	61	81[11]	38	44
			Starved Rock	231	600	110	19	1933	6.2	1,532	61	81	38	44
			Marseilles	245	600	110	24	1933	5.9	1,543	61	81	48	55
			Dresden Island	272	600	110	22	1933	6.0	1,532	61	81	38	44
		Des Plaines R.	Brandon Road	286	600	110	34	1933	6.0	1,543	61	81	30	44
		Chicago Sanitary and Ship Canal	Lockport	291	600	110	40	1933	5.3	1,511	[illegible]	81	42	56
		Calumet R.	T.J. O'Brien	327	1,000	110	5	1960	2.2	1,212	61	75	21	[illegible]

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Width (feet)	Lift (feet)	Double Lockage Variables Intercept	Slope	Interference Parameter[5]
Lower Upper Mississippi	Lower Upper Mississippi	Mississippi R., Illinois R. to Missouri R.	L&D 26	203	600	110	15	-0.43	0.12	1.00
			L&D 26	203	360	110	15	-0.70	0.28	1.00
	Middle Mississippi	Mississippi R., Missouri R. to Ohio R. (Chain of Rocks Canal)	L&D 27	185	1,200	110	13	0.00[6]	0.00[6]	1.00
			L&D 27	185	600	110	13	-0.43	0.12	1.00
Baton Rouge to Gulf	Ouachita, Black, Red	Black R.	Jonesville	25	600	84	30	-0.43	0.12	1.00
		Ouachita R.	Columbia	117	600	84	18	-0.43	0.12	1.00
			L&D 6	223	268	[illegible]	10	-0.54	0.28	1.00
			L&D 8	281	268	55	14	-0.54	0.28	1.00
		Red R., mouth to Shreveport	L&D 1[7]	NA	685	84		-0.43	0.12	1.00
	Old and Atchafalaya	Old R.	Old River[6]	304	1,200	75	32	0.00[6]	0.00	1.00
	Baton Rouge - Morgan City Bypass	Port Allen Route	Port Allen[6]	228	1,198	84	45	0.00[6]	0.00	1.00
			Bayou Sorrel[6]	37	800	75	21	0.00[6]	0.00	1.00
		Bayou Teche	Berwick	116	307	45	11	-0.54	0.28	1.00
Illinois River	Illinois Waterway	Illinois R.	LaGrange	80	600	110	10	-0.43	0.12	1.00
			Peoria	154	600	110	11	-0.43	0.12	1.00
			Starved Rock	231	600	110	19	-0.43	0.12	1.00
			Marseilles	245	600	110	24	-0.43	0.12	1.00
			Dresden Island	272	600	110	22	-0.43	0.12	1.00
		Des Plaines R.	Brandon Road	286	600	110	34	-0.43	0.12	1.00
		Chicago Sanitary and Ship Canal	Lockport	291	600	110	40	-0.43	0.12	1.00
		Calumet R.	T.J. O'Brien	[illegible]	1,000	110	5	0.00[6]	0.00	1.00

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Vessel or Tow Size	Average Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight	Lock Cycle Times (minutes) Turnback[4]
Ohio River	Upper Ohio	Ohio River, confluence of Allegheny and Monongahela Rivers to Kanawha River	Emsworth	6	600	110	18	1921	6.8	1,046	55%	86%	39	45
			Emsworth	6	360	56	18	1921	2.0	910	43	89	33	36
			Dashields	13	600	110	10	1929	7.3	1,046	55	86	35	37
			Dashields	13	360	56	10	1929	1.7	910	43	89	33	36
			Montgomery	32	600	110	18	1936	7.7	1,046	55	86	35	37
			Montgomery	32	360	56	18	1936	1.5	910	43	89	33	36
			Cumberland	54	1,200	110	21	1961	9.3	1,590	62	86	46	39
			Cumberland	54	600	110	21	1961	4.0	1,598	30	85	40	36
			Pike Island	84	1,200	110	21	1963	9.2	1,348	64	86	40	42
			Pike Island	84	600	110	21	1963	3.0	1,453	40	85	30	36
			Hannibal	126	1,200	110	21	1975	10.1	1,348	64	86	40	42
			Hannibal	126	600	110	21	1975	3.1	1,453	40	85	30	36
			Willow Island	162	1,200	110	20	1975	9.5	1,348	64	86	40	42
			Willow Island	162	600	110	20	1975	3.5	1,453	40	85	30	36
			Belleville	204	1,200	110	22	1968	9.7	1,348	64	86	40	42
			Belleville	204	600	110	22	1968	2.9	1,453	40	85	30	36
			Racine	238	1,200	110	22	1968	9.5	1,348	64	86	40	42
			Racine	238	600	110	22	1968	3.6	1,453	40	85	30	36
	Middle Ohio	Ohio River, Kanawha River to Kentucky River	Gallipolis	279	600	110	23	1937	9.4	1,368	59	85	39	30
			Gallipolis	279	360	110	23	1937	4.1	1,072	45	86	32	36
			Greenup	341	1,200	110	30	1962	8.3	1,590	62	86	46	39
			Greenup	341	600	110	30	1962	4.0[12]	1,598	30	85	40	36
			Meldahl	436	1,200	110	30	1962	8.7	1,348	64	86	40	42
			Meldahl	436	600	110	30	1962	3.0	1,453	40	85	30	36
			Markland	532	1,200	110	35	1963	8.2	1,348	[illegible]	86	40	42
			Markland	532	600	110	35	1963	2.5	1,453	[illegible]	85	30	36
	Lower Ohio Three	Ohio River, Kentucky River to Green River	McAlpine[13]	607	1,200	110	37	1961	7.8	1,550	62	87	49	46
			McAlpine	607	600	110	37	1930	4.3[14]	1,780	36	86	62	62
			Cannelton	721	1,200	110	25	1975	9.2	1,580	62	86	46	39
			Cannelton	721	600	110	25	1975	3.5	1,598	30	85	40	36
			Newburgh	776	1,200	110	33	1978	8.6	1,590	62	86	46	39
			Newburgh	776	600	110	33	1978	5.1	1,598	30	85	40	36

Table C-2

Data for Lock Capacity Analysis

(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Double Lockage Variables Intercept	Double Lockage Variables Slope	Interference Parameter
Ohio River	Upper Ohio	Ohio River, confluence of Allegheny and Monongahela Rivers to Kanawha River	Emsworth	6	600	110	18	-0.43	0.12	1.00
			Emsworth	6	360	56	18	-0.54	0.28	1.00
			Dashields	13	600	110	10	-0.43	0.12	1.00
			Dashields	13	360	56	10	-0.54	0.28	0.70
			Montgomery	32	600	110	18	-0.43	0.12	1.00
			Montgomery	32	360	56	18	-0.54	0.28	0.70
			Cumberland	54	1,200	110	21	0.00[6]	0.00	1.00
			Cumberland	54	600	110	21	-0.43	0.12	0.90
			Pike Island	84	1,200	110	21	0.00[6]	0.00	1.00
			Pike Island	84	600	110	21	-0.43	0.12	0.85
			Hannibal	126	1,200	110	21	0.00[6]	0.00	1.00
			Hannibal	126	600	110	21	-0.43	0.12	0.85
			Willow Island	162	1,200	110	20	0.00[6]	0.00	1.00
			Willow Island	162	600	110	20	-0.43	0.12	0.85
			Belleville	204	1,200	110	22	0.00[6]	0.00	1.00
			Belleville	204	600	110	22	-0.43	0.12	0.85
			Racine	238	1,200	110	22	0.00[6]	0.00	1.00
			Racine	238	600	110	22	-0.43	0.12	0.85
	Middle Ohio	Ohio River, Kanawha River to Kentucky River	Gallipolis	279	600	110	23	-0.43	0.12	1.00
			Gallipolis	279	360	110	23	-0.70	0.28	0.70
			Greenup	341	1,200	110	30	0.00[6]	0.00	1.00
			Greenup	341	600	110	30	-0.43	0.12	0.90
			Meldahl	436	1,200	110	30	0.00[6]	0.00	1.00
			Meldahl	436	600	110	30	-0.43	0.12	0.85
			Markland	532	1,200	110	35	0.00[6]	0.00	1.00
			Markland	532	600	110	35	-0.43	0.12	0.85
	Lower Ohio Three	Ohio River, Kentucky River to Green River	McAlpine[11]	607	1,200	110	37	0.00[6]	0.00	1.00
			McAlpine	607	600	110	37	-0.43	0.12	1.00
			Cannelton	721	1,200	110	25	0.00[6]	0.00	1.00
			Cannelton	721	600	110	25	-0.43	0.12	0.90
			Newburgh	776	1,200	110	33	0.00[6]	0.00	1.00
			Newburgh	776	600	110	33	-0.43	0.12	0.90

Table C-2

Data for Lock Capacity Analysis

(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Vessel or Tow Size	Average Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight[3]	Lock Cycle Times (minutes) Turnback[4]
Ohio River	Lower Ohio Two	Ohio River, Green River to Tennessee River	Uniontown	846	1,200	110	22	1975	9.4	1,590	62%	86%	46	33
			Uniontown	846	600	110	22	1975	5.5[14]	1,598	30	85	40	36
			Smithland	919	1,200	110	22	1980	9.4	1,590	62	82	46	33
			Smithland	919	1,200	110	22	1980	9.4	1,590	62	82	46	33
	Lower Ohio One	Ohio River, Tennessee River to Mouth	L&D 52	939	1,200	110	12	1928	8.8	1,546	62	OP[15]	73	80
			L&D 52	939	600	110	12	1928	3.5	1,655	45	OP[15]	39	40
			L&D 53	963	600	110	13	1929	8.2	1,552	61	OP[16]	48	41
	Monongahela River	Monongahela River	L&D 2	11	720	110	9	1951	6.5	1,014	55	90	30	39
			L&D 2	11	360	56	9	1953	1.6	815	44	90	19	24
			L&D 3	24	720	56	8	1907	5.9	909	52	83	32	34
			L&D 3	24	360	56	8	1907	1.9	897	48	86	26	31
			L&D 4	42	720	56	17	1932	5.8	909	52	83	32	34
			L&D 4	42	360	56	17	1932	1.9	897	48	86	26	31
			Maxwell	61	720	84	20	1965	6.0	921	31	90	38	36
			Maxwell	61	720	84	20	1965	6.0	906	77	90	38	37
			L&D 7	85	360	56	15	1926	4.7	909	51	86	26	31
			L&D 8	91	360	56	19	1926	4.9	909	51	86	26	31
			Morgantown	102	600	84	17	1950	3.9	917	50	86	26	41
			Hildebrand	108	600	84	21	1960	3.6	917	50	86	26	41
			Opekiska	115	600	84	22	1968	1.6	917	50	86	26	41
	Allegheny River	Allegheny R.	L&D 2	7	360	56	11	1934	3.2	909	51	86	26	31
			L&D 3	15	360	56	14	1934	3.2	909	51	86	26	31
			L&D 4	24	360	56	11	1927	3.2	909	51	86	26	31
			L&D 5	30	360	56	12	1927	3.2	909	51	86	26	31
			L&D 6	36	360	56	12	1928	3.2	909	51	86	26	31
			L&D 7	46	360	56	13	1931	3.2	909	51	86	26	31
			L&D 8	53	360	56	18	1937	3.2	909	51	86	26	31
			L&D 9	62	360	56	22	1938	3.2	909	51	86	26	31

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Double Lockage Variables Intercept	Double Lockage Variables Slope	Interference Parameter[5]
Ohio River	Lower Ohio Two	Ohio River, Green River to Tennessee River	Uniontown	846	1,200	110	22	0.00[6]	0.00	1.00
			Uniontown	846	600	110	22	-0.43	0.12	0.90
			Smithland	919	1,200	110	22	0.00[6]	0.00	1.00
			Smithland	919	1,200	110	22	0.00[6]	0.00	1.00
	Lower Ohio One	Ohio River, Tennessee River to Mouth	L&D 52	939	1,200	110	12	0.00[6]	0.00	1.00
			L&D 52	939	600	110	12	-0.43	0.12	0.94
			L&D 53	963	600	110	13	-0.43	0.12	1.00
	Monongahela River	Monongahela River	L&D 2	11	720	110	9	-0.54	0.11	1.00
			L&D 2	11	360	56	9	-0.54	0.28	0.70
			L&D 3	24	720	56	8	-0.48	0.11	1.00
			L&D 3	24	360	56	8	-0.54	0.28	0.70
			L&D 4	42	720	56	17	-0.48	0.11	1.00
			L&D 4	42	360	56	17	-0.54	0.28	0.70
			Maxwell	61	720	84	20	-0.51	0.11	1.00
			Maxwell	61	720	84	20	-0.51	0.11	1.00
			L&D 7	85	360	56	15	-0.54	0.28	1.00
			L&D 8	91	360	56	19	-0.54	0.28	1.00
			Morgantown	102	600	84	17	-0.60	0.17	1.00
			Hildebrand	108	600	84	21	-0.60	0.17	1.00
			Opekiska	115	600	84	22	-0.60	0.17	1.00
	Allegheny River	Allegheny R.	L&D 2	7	360	56	11	-0.54	0.28	1.00
			L&D 3	15	360	56	14	-0.54	0.28	1.00
			L&D 4	24	360	56	11	-0.54	0.28	1.00
			L&D 5	30	360	56	12	-0.54	0.28	1.00
			L&D 6	36	360	56	12	-0.54	0.28	1.00
			L&D 7	46	360	56	13	-0.54	0.28	1.00
			L&D 8	53	360	56	18	-0.54	0.28	1.00
			L&D 9	62	360	56	22	-0.54	0.28	1.00

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Tow Size	Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight[3]	Lock Cycle Times (minutes) Turnback[4]
Ohio River	Kanawha River	Kanawha R.	Winfield	31	360	56	28	1937	4.6	1,288	59%	77%	71	32
			Winfield	31	360	56	28	1937	4.1	1,137	46	77	58	34
			Marmet	68	360	56	24	1934	4.8	1,288	59	77	71	32
			Marmet	68	360	56	24	1934	3.0	1,137	46	77	58	34
			London	83	360	56	24	1934	3.8	1,288	59	77	71	32
			London	83	360	56	24	1934	3.4	1,137	46	77	58	34
	Kentucky River	Kentucky R.	L&D 1	4	145	38	8	1839	2.0	909	50	86	26	32
			L&D 2	31	145	38	14	1839	2.0	909	50	86	26	32
			L&D 3	42	145	38	13	1844	2.0	909	50	86	26	32
			L&D 4	65	145	38	13	1844	2.0	909	50	86	26	32
			L&D 5	82	145	38	15	1844	2.0	909	50	86	26	32
			L&D 6	96	147	52	14	1891	2.0	909	50	86	26	32
			L&D 7	117	147	52	15	1897	2.0	909	50	86	26	32
			L&D 8	140	146	52	18	1900	2.0	909	50	86	26	32
			L&D 9	158	148	52	18	1907	2.0	909	50	86	26	32
			L&D 10	176	148	52	17	1907	2.0	909	50	86	26	32
			L&D 11	201	148	52	18	1906	2.0	909	50	86	26	32
			L&D 12	221	148	52	17	1910	2.0	909	50	86	26	32
			L&D 13	240	148	52	17	1915	2.0	909	50	86	26	32
			L&D 14	249	148	52	17	1917	2.0	909	50	86	26	32
	Green River	Green R.	L&D 1	9	600	84	12	1956	3.8	1,497	50	80	22	29
			L&D 2	63	600	84	14	1956	3.8	1,497	50	80	22	29

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Width (feet)	Lift (feet)	Double Lockage Variables Intercept	Slope	Interference Parameter
Ohio River	Kanawha River	Kanawha R.	Winfield	31	360	56	28	-0.54	0.28	1.00
			Winfield	31	360	56	28	-0.54	0.28	0.80
			Marmet	68	360	56	24	-0.54	0.28	1.00
			Marmet	68	360	56	24	-0.54	0.28	0.80
			London	83	360	56	24	-0.54	0.28	1.00
			London	83	360	56	24	-0.54	0.28	0.80
	Kentucky River	Kentucky R.	L&D 1	4	145	38	8	0.00	1.00[17]	1.00
			L&D 2	31	145	38	14	0.00	1.00[17]	1.00
			L&D 3	42	145	38	13	0.00	1.00[17]	1.00
			L&D 4	65	145	38	13	0.00	1.00[17]	1.00
			L&D 5	82	145	38	15	0.00	1.00[17]	1.00
			L&D 6	96	147	52	14	0.00	1.00[17]	1.00
			L&D 7	117	147	52	15	0.00	1.00[17]	1.00
			L&D 8	140	146	52	18	0.00	1.00[17]	1.00
			L&D 9	158	148	52	18	0.00	1.00[17]	1.00
			L&D 10	176	148	52	17	0.00	1.00[17]	1.00
			L&D 11	201	148	52	18	0.00	1.00[17]	1.00
			L&D 12	221	148	52	17	0.00	1.00[17]	1.00
			L&D 13	240	148	52	17	0.00	1.00[17]	1.00
			L&D 14	249	148	52	17	0.00	1.00[17]	1.00
	Green River	Green R.	L&D 1	9	600	84	12	-0.60	0.17	1.00
			L&D 2	63	600	84	14	-0.60	0.17	1.0

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Tow Size	Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight	Lock Cycle Times (minutes) Turnback[4]
Ohio River	Cumberland River	Cumberland R.	Barkley	31	800	110	57	1964	10.7	1,673	59%	85%	47	59
			Cheatham	149	800	110	25	1959	5.7	1,673	59	85	47	59
			Old Hickory	216	400	84	60	1957	1.6	1,914	50	82	31	50
			Cordell Hull	314	400	84	59	1973	1.6	1,914	50	82	31	50
Tennessee River	Upper Tennessee and Clinch	Tennessee R., head of navigation to junction with Tenn. Tom.	Wilson	259	600	110	94	1959	7.1	1,516	58	85	46	53
			Wheeler	275	600	110	48	1944	7.7	1,046	55	77	35	37
			Wheeler	275	400	60	48	1944	1.0	910	43	80	33	36
			Guntersville	349	600	110	39	1962	6.8	1,046	55	77	35	37
			Guntersville	349	360	60	39	1939	1.0	910	43	79	33	36
			Nickajack	425	600	110	39	1967	5.5	1,516	58	85	46	53
			Chickamauga	471	360	[illegible]	49	1940	4.0	909	51	86	26	31
			Watts Bar	530	360	60	58	1942	4.0	909	51	86	26	31
			Ft. Loudon	602	360	60	72	1943	4.0	909	51	86	26	31
		Clinch R.	Melton Hill	23	400	75	58	1963	1.5	1,083	29[18]	97	28	46
	Lower Tennessee	Tennessee R. junction with Tenn. Tom. to mouth	Kentucky	22	600	110	56	1944	6.9	1,516	58	85	46	53
			Pickwick	207	600	110	55	1937	7.7	1,584	56	85	51	61

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Width (feet)	Lift (feet)	Double Lockage Variables Intercept	Slope	Interference Parameter[5]
Ohio River	Cumberland River	Cumberland R.	Barkley	31	800	110	57	-0.54	0.11	1.00
			Cheatham	149	800	110	25	-0.54	0.11	1.00
			Old Hickory	216	400	84	60	-0.70	0.28	1.00
			Cordell Hull	314	400	84	59	-0.70	0.28	1.00
Tennessee River	Upper Tennessee and Clinch	Tennessee R., head of navigation to junction with Tenn. Tom.	Wilson	259	600	110	94	-0.43	0.12	1.00
			Wheeler	275	600	110	48	-0.43	0.12	1.00
			Wheeler	275	400	60	48	-0.54	0.28	0.70
			Guntersville	349	600	110	39	-0.43	0.12	1.00
			Guntersville	349	360	60	39	-0.54	0.28	0.70
			Nickajack	425	600	110	39	-0.43	0.12	1.00
			Chickamauga	471	360	60	49	-0.54	0.28	1.00
			Watts Bar	530	360	60	58	-0.54	0.28	1.00
			Ft. Loudon	602	160	60	72	-0.54	0.28	1.00
		Clinch R.	Melton Hill	23	400	75	58	-0.43	0.12	1.00
	Lower Tennessee	Tennessee R. junction with Tenn. Tom. to mouth	Kentucky	22	600	110	56	-0.43	0.12	1.00
			Pickwick	207	600	110	55	-0.43	0.12	1.00

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Tow Size	Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes)[3] Straight	Lock Cycle Times (minutes) Turnback[4]
Arkansas River	Arkansas, Verdigris, White and Black Rivers	Arkansas R.	Norrel	10	600	110	30	1967	3.7	1,381	59%	99%	31	43
			L&D 2	13	600	110	20	1968	3.8	1,381	59	99	31	43
			L&D 3	50	600	110	20	1969	3.9	1,381	59	99	31	43
			L&D 4	66	600	110	14	1969	4.[illegible]	1,381	59	99	31	43
			L&D 5	86	600	110	17	1969	3.4	1,381	59	99	31	43
			Terry	108	600	110	18	1969	3.6	1,381	59	99	31	43
			Murray	125	600	110	18	1970	3.8	1,381	59	99	31	43
			Toad Suck	156	600	110	16	1970	3.6	1,381	59	99	31	43
			L&D 9	177	600	110	20	1970	3.8	1,381	59	99	31	43
			Dardanelle	206	600	110	55	1965	3.7	1,381	59	99	31	43
			Ozark	257	600	110	34	1973	3.8	1,381	59	99	31	43
			L&D 13	293	600	110	20	1970	3.7	1,381	59	99	31	43
			Mayo	320	600	110	21	1971	3.4	1,381	59	99	31	43
			Kerr	336	600	110	48	1969	3.4	1,381	59	99	31	43
			Webbers Falls	369	600	110	30	1970	3.0	1,381	59	99	31	43
		Verdigris	Chouteau	7	600	110	21	1971	2.8	1,381	59	99	31	43
			Graham	27	600	110	21	1971	2.8	1,381	59	99	31	43
Gulf Coast West	GIWW West One	Gulf Intra-coastal Water-way	Harvey	0	425	75	20	1935	1.3	1,133	54	94	25	36
			Algiers	10	797	75	18	1956	2.4	1,736	64	97	33	42
			Bayou Bouef	93	1,158	75	11	1956	2.5	1,851	71	OP[19]	29	28
			Vermilion[20]	163	1,200	56	5	1934	2.4	1,928	56	OP[21]	27	27
			Calcasieu	239	1,204	75	4	1950	2.5	1,851	71	OP[22]	29	27
Gulf Coast East	GIWW East One	Inner Harbor Navigation Canal	Inner Harbor	6	640	75	17	1923	2.2	1,685	57	88[23]	29	30
		Pearl River	L&D 1	30	356	65	27	1951	4.7	909	51	86	26	31

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions: Length (feet)	Chamber Dimensions: Width (feet)	Chamber Dimensions: Lift (feet)	Double Lockage Variables: Intercept	Double Lockage Variables: Slope	Interference Parameter
Arkansas River	Arkansas, Verdigris, White and Black Rivers	Arkansas R.	Norrel	10	600	110	30	-0.43	0.12	1.00
			L&D 2	13	600	110	20	-0.43	0.12	1.00
			L&D 3	50	600	110	20	-0.43	0.12	1.00
			L&D 4	66	600	110	14	-0.43	0.12	1.00
			L&D 5	86	600	110	17	-0.43	0.12	1.00
			Terry	108	600	110	18	-0.43	0.12	1.00
			Murray	125	600	110	10	-0.43	0.12	1.00
			Toad Suck	156	600	110	16	-0.43	0.12	1.00
			L&D 9	177	600	110	20	-0.43	0.12	1.00
			Dardanelle	206	600	110	55	-0.43	0.12	1.00
			Ozark	257	600	110	34	-0.43	0.12	1.00
			L&D 13	293	600	110	20	-0.43	0.12	1.00
			Mayo	320	600	110	21	-0.43	0.12	1.00
			Kerr	336	600	110	48	-0.43	0.12	1.00
			Webbers Falls	369	600	110	30	-0.43	0.12	1.00
		Verdigris	Chouteau	7	600	110	21	-0.43	0.12	1.00
			Graham	27	600	110	21	-0.43	0.12	1.00
Gulf Coast West	GIWW West One	Gulf Intra-coastal Water-way	Harvey	0	425	75	20	0.00[24]	0.00	1.00
			Algiers	10	797	75	18	0.00[24]	0.00	1.00
			Bayou Bouef	93	1,158	75	11	0.00	0.00	1.00
			Vermilion[17]	163	1,200	56	5	1.00	0.00	1.00
			Calcasieu	239	1,204	75	4	1.00	0.00	1.00
Gulf Coast East	GIWW East One	Inner Harbor Navigation Canal	Inner Harbor	6	640	75	17	0.00[24]	0.00	1.00
		Pearl River	L&D 1	30	356	65	27	0.54	0.28	1.00

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Chamber Dimensions Width (feet)	Chamber Dimensions Lift (feet)	Year Built	Average Tow Size	Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight[3]	Lock Cycle Times (minutes) Turnback[4]
Gulf Coast East	Apalachicola, Chattahoochee, Flint Rivers	Apalachicola River	Woodruff	108	450	82	33	1957	2.0	997	49%	76%	23	34
		Chattahoochee River	Andrews	153	450	82	88	1963	1.4	997	49	76	23	34
			George	182	450	82	25	1963	1.2	997	49	76	23	34
Mobile River and Tributaries	Black Warrior - Mobile Harbor	Warrior R.	Bankhead	374	600	110	68	1975	3.6	1,502	65	76	45	62
			Holt	347	600	110	64	1966	3.7	1,502	65	76	45	62
			Oliver	338	460	95	28	1940	3.4	1,508	67	76	41	44
			Warrior	261	600	110	22	1957	3.4	1,502	65	76	45	62
		Tombigbee R.	Demopolis	213	600	110	40	1956	3.5[25]	1,490	67	94	44	49
			Coffeeville	119	600	110	34	1961	3.5[25]	1,490	67	94	34	40
	Alabama-Coosa	Alabama R.	Claiborne	82	600	84	30	1973	3.5	1,490	67	94	44	49
			Millers Ferry	142	600	84	45	1969	3.5	1,490	67	94	44	49
			Jones Bluff	245	600	84	45	1974	3.5	1,490	67	94	44	49
	Tennessee-Tombigbee Waterway	Tennessee[26] Tombigbee Waterway	Gainesville	266	600	110	36	1978	6.0	1,500	50	89	30	38
			Aliceville	311	600	110	27	1979	6.0	1,500	50	89	30	38
			Columbus	333	600	110	27	1980	6.0	1,500	50	89	30	38
			Aberdeen	356	600	110	27	1985	6.0	1,500	50	89	30	38
			A	369	600	110	30	1986	6.0	1,500	50	89	30	39
			B	374	600	110	25	1986	6.0	1,500	50	89	30	38
			C	389	600	110	25	1986	6.0	1,500	50	89	30	38
			D	396	600	110	30	1986	6.0	1,500	50	89	30	38
			E	405	600	110	30	1986	6.0	1,500	50	89	30	38
			Bay Springs	410	600	110	84	1986	6.0	1,500	50	89	30	38

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Width (feet)	Lift (feet)	Double Lockage Variables Intercept	Slope	Interference Parameter[5]
Gulf Coast East	Apalachicola, Chattahoochee, Flint Rivers	Apalachicola River	Woodruff	108	450	82	33	-0.60	0.20	1.00
		Chattahoochee River	Andrews	153	450	82	88	-0.60	0.17	1.00
			George	182	450	82	25	-0.60	0.17	1.00
Mobile River and Tributaries	Black Warrior - Mobile Harbor	Warrior R.	Bankhead	374	600	110	68	-0.43	0.12	1.00
			Holt	347	600	110	64	-0.43	0.12	1.00
			Oliver	338	460	95	28	-0.70	0.28	1.00
			Warrior	261	600	110	22	-0.43	0.12	1.00
		Tombigbee R.	Demopolis	213	600	110	40	-0.00[27]	0.00	1.00
			Coffeeville	119	600	110	34	-0.00[27]	0.00	1.00
	Alabama-Coosa	Alabama R.	Claiborne	82	600	84	30	-0.43	0.12	1.00
			Millers Ferry	142	600	84	45	-0.43	0.12	1.00
			Jones Bluff	245	600	84	45	-0.43	0.12	1.00
	Tennessee-Tombigbee Waterway	Tennessee[26] Tombigbee Waterway	Gainesville	266	600	110	36	0.00	0.00	1.00
			Aliceville	311	600	110	27	0.00	0.00	1.00
			Columbus	333	600	110	27	0.00	0.00	1.00
			Aberdeen	356	600	110	27	0.00	0.00	1.00
			A	369	600	110	30	0.00	0.00	1.00
			B	374	600	110	25	0.00	0.00	1.00
			C	389	600	110	25	0.00	0.00	1.00
			D	396	600	110	30	0.00	0.00	1.00
			E	405	600	110	30	0.00	0.00	1.00
			Bay Springs	410	600	110	84	0.00	0.00	1.00

Table C-2

Data for Lock Capacity Analysis
(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Width (feet)	Lift (feet)	Year Built	Average Tow Size	Vessel or Barge Lading (tons)	Percent Loaded[1]	Chamber Availability[2]	Lock Cycle Times (minutes) Straight[3]	Turnback[4]
Great Lakes St. Lawrence Seaway - New York State Waterways	Lake Ontario and St. Lawrence Seaway	St. Lawrence River	St. Lambert	3	766	80	16	1959	NA	18,879	70%	47%[28]	39	NA
			Cote Ste. Catherine	10	766	80	34	1959	NA	18,879	70	47[28]	39	NA
			Lower Beauharnois	28	766	80	40	1959	NA	18,879	70	47[28]	39	NA
			Upper Beauharnois	28	766	80	38	1959	NA	18,879	70	47[28]	39	NA
			Snell	72	766	80	49	1959	NA	18,879	70	47[28]	39	NA
			Eisenhower	76	766	80	42	1959	NA	18,879	70	47[28]	39	NA
			Iroquois	98	766	80	6	1959	NA	18,879	70	47[28]	39	NA
		Welland Canal	1	2	766	80	46	NA	NA	18,879	79	41[29]	44	NA
			2	3	766	80	46	NA	NA	18,879	79	41[29]	44	NA
			3	6	766	80	46	NA	NA	18,879	79	41[29]	44	NA
			4	7	766	80	46	NA	NA	18,879	79	82[29,30]	44	NA
			5	7	766	80	46	NA	NA	18,879	79	82[29,30]	44	NA
			6	7	766	80	46	NA	NA	18,879	79	82[29,30]	44	NA
			7	8	766	80	46	NA	NA	18,879	79	41[29]	44	NA
			8	21	1,148	80	3	NA	NA	18,879	79	41[29]	44	NA
	Lake Huron	St.Mary's R.	New Poe	47	1,200	110	21	1968	NA	25,500	80	47[28]	75	NA
			Mac Arthur	47	800	80	21	1925	NA	18,879	57	47[28]	44	NA
Columbia-Snake Waterway-Willamette River	Upper Columbia-Snake	Snake R.	Lower Granite	108	675	86	100	1975	3.0	2,276	52	64	33	28
			Little Goose	70	675	86	98	1970	3.0	2,276	52	64	33	28
			Lower Monumental	42	675	86	100	1969	3.0	2,276	52	64	33	28
			Ice Harbor	10	675	86	100	1962	3.0	2,276	52	64	33	28
		Columbia R.	McNary	292	675	86	75	1953	3.0	2,276	52	64	33	28
			John Day	216	675	86	105	1968	3.0	2,276	52	64	33	28
			The Dalles	192	675	86	85	1957	3.0	2,276	52	64	33	28
			Bonneville	146	556	76	58	1937	3.0	1,728	52	64	44	41

Table C-2

Data for Lock Capacity Analysis

(Includes Commercially Important Locks for Which Traffic and Capacity Data Were Available)

NWS Region	NWS Segment	River/ Waterway	Lock Name	River Mile	Chamber Dimensions Length (feet)	Width (feet)	Lift (feet)	Double Lockage Variables Intercept	Slope	Interference Parameter[5]
Great Lakes St. Lawrence Seaway - New York State Waterways	Lake Ontario and St. Lawrence Seaway	St. Lawrence River	St. Lambert	3	766	80	16	0.00	0.00	1.00
			Cote Ste. Catherine	10	766	80	34	0.00	0.00	1.00
			Lower Beauharnois	28	766	80	40	0.00	0.00	1.00
			Upper Beauharnois	28	766	80	38	0.00	0.00	1.00
			Snell	72	766	80	49	0.00	0.00	1.00
			Eisenhower	76	766	80	42	0.00	0.00	1.00
			Iroquois	98	766	80	6	0.00	0.00	1.00
		Welland Canal	1	2	766	80	46	0.00	0.00	1.00
			2	3	766	80	46	0.00	0.00	1.00
			3	6	766	80	46	0.00	0.00	1.00
			4	7	766	80	46	0.00	0.00	1.00
			5	7	766	80	46	0.00	0.00	1.00
			6	7	766	80	46	0.00	0.00	1.00
			7	8	766	80	46	0.00	0.00	1.00
			8	21	1,148	80	3	0.00	0.00	1.00
	Lake Huron	St.Mary's R.	New Poe	47	1,200	110	21	0.00	0.00	1.00
			Mac Arthur	47	800	80	21	0.00	0.00	1.00
Columbia-Snake Waterway-Willamette River	Upper Columbia-Snake	Snake R.	Lower Granite	108	675	86	100	-2.00	0.50	1.00
			Little Goose	70	675	86	98	-2.00	0.50	1.00
			Lower Monumental	42	675	86	100	-2.00	0.50	1.00
			Ice Harbor	10	675	86	100	-2.00	0.50	1.00
		Columbia R.	McNary	292	675	86	75	-2.00	0.50	1.00
			John Day	216	675	86	105	-2.00	0.50	1.00
			The Dalles	192	675	86	85	-2.00	0.50	1.00
			Bonneville	146	556	76	58	-1.40	0.70	1.00

Table C-2

SOURCES: U.S. Army, Corps of Engineers, 1977 Performance Monitoring Statistics collected by Lockmasters; U.S. Army, Corps of Engineers, Physical Characteristics of Inland Waterways, 1975; U.S. Army, Corps of Engineers, North Central Division; various studies of the Great Lakes system, including the season extension studies; NWS Inventory.

NA = Not Available or Not Applicable.

NOTES:

1 The number of loaded barges or vessels divided by the total number of barges or vessels passing a lock.

2 Chamber availability is the amount of time during 1977 that a chamber was available for processing commercial traffic, after taking into account downtime for repairs, maintenance, high winds, fog, ice formation, high water conditions, low water conditions, and other unfavorable operating conditions. In addition, an adjustment is made for the effects of seasonal variation in traffic (using 1976 monthly Performance Monitoring data, on annual lock capacity.

3 This is the time required for a vessel or tow to approach a lock chamber, enter a lock chamber, be raised or lowered, and then exit a lock chamber, assuming that the chamber is at the correct level.

4 This is the time required for a vessel or tow to complete a lockage following another tow or vessel in the same direction. The cycle time components are usually shorter, but an additional cycling of the chamber (turnback) is required. The sequence is to turnback the chamber, approach the chamber, enter the chamber, raise or lower the vessel or tow, and exit the chamber.

5 The interference parameter is an adjustment coefficient used to capture the interaction between chambers at multichamber faci .ties. For single chamber facilities, it is set equal to one.

6 No double lockages occur.

7 Data for Red River Lock 1 is based on representative data. Year built is projected completion date.

8 Bayou Sorrel operates as open pass 90 percent of the time. No other data were available and it was not considered necessary to puruse any more data.

9 Open pass 90 percent of the time.

10 Open pass 40 percent of the time. The time of the year that open pass is available does not coincide with peak traffic.

11 Open pass 35 percent of the time. The time of the year that open pass is available does not coincide with peak traffic.

12 Tow size was adjusted downward from base year data. Base year data included an extended period of closure of the main chamber.

13 Data for McAlpine excludes a third small (360' x 56') chamber.

14 Tow size at auxiliary chamber was adjusted upwards from base year to reflect greater utilization likely under more congested conditions.

15 Open pass 60 percent of the time.

16 Open pass 94 percent of the time.

17 All lockages are double (or more) lockages.

18 Percent loaded for Walton Hill is unusually low and is probably an error in the data base. The apparent error did not affect the results of the analysis and the matter was not pursued.

19 Open pass 90 percent of the time.

20 Data shown is for the existing chamber. The new chamber is not expected to operate significantly differently.

21 Open pass 78 percent of the time. Neither the existing chamber nor the new chamber is viewed as constraining.

22 Open pass 60 percent of the time.

23 Availability was adjusted downwards to account for usage by deep draft vessels.

24 Double lockages were assumed constant over time. See table C-1.

25 Data shown was reported for base year. Capacity was evaluated using a tow size of approximately 5.5 in 1990 and thereafter after the Tennessee-Tombigbee Waterway is projected to open.

26 Data for Tennessee-Tombigbee locks is representative data only. Years built are either actual or projected completion dates.

27 No double lockages are forecast.

28 Availability was adjusted downward by 20% to allow for utilization by Canadian traffic.

29 Availability was adjusted downward by 30% to allow for Canadian traffic.

30 Reflects dual chambers at this site.

APPENDIX D

LINE-HAUL COST METHODOLOGY AND DATA

APPENDIX D

LINE-HAUL COST METHODOLOGY AND DATA

INTRODUCTION

This appendix serves two purposes. These are to present the methodology used to project changes in line-haul costs (a key evaluation measure) and to present the basic data used for the model presented. Examples of calculations are included to illustrate the procedure. It is impossible to present all of the calculations since some key factors which influence the results were never produced externally to the computer. Where these factors come into play are pointed out in the text of this appendix.

The remainder of ths appendix is organized as follows:

- o First, the basic concepts underlying the methodology are explained.
- o Second, the basic model used for analysis segment specific and commodity specific calculations is described and examples are shown.
- o Third, the methodology for computing regional averages of line-haul cost is presented, with example calculations.
- o Finally, a large table of data is presented.

LINE-HAUL COST EVALUATION CONCEPT

As discussed in Section IV of this report, line-haul cost is a key component of capability and is strongly influenced by the characteristics of the navigation system. Thus domestic line-haul cost was idertified as a key evaluation measure for the present system and for strategies. The concepts that were developed were designed for the sole purpose of providing this evaluation for NWS.

The basic approach was to specify commodity groupings for costing purposes, develop equations of sufficient generality to capture the wide range of operating conditions, develop data to serve the equations, and compute averages for regional, industry, and national evaluations.

The four costing groups were dry bulk commodities, iron and steel products, liquid bulk products, and other commodities. These groupings were defined because the differences among them were great enough to justify separate treatment. Only four groupings were defined because more detailed treatment was deemed to be unwarranted for NWS purposes. Thus, for example, coal and grain were both assigned to the same costing group. The assignment scheme was based on the fourteen NWS Reporting Commodities and is shown in Table D-1 below, along with the assignments to major industries.

While most of the costing group assignments are self explanatory, one assignment deserves special mention. Iron and steel products was given a special grouping since barges carrying these commodities on the inland shallow draft system are often light loaded.

Given the costing group definitions, additional data was sought concerning key variables for each costing group for each analysis segment. Data was gathered from a variety of sources, including prior NWS work, other studies and publications, and telephonic interviews with operators, lock masters, etc. The data was reviewed and final values were assigned.

A key concern was tow sizes on the shallow draft system. The basic philosophy was to select tow size/barge size combinations that represented highly efficient, though not necessarily the most efficient, operations. The rationale for this approach is that the efficient operations establish the price in competitive markets. Thus it was not necessary to develop detailed statistical descriptions of tow sizes. Tow sizes were applied uniformly for the relevant commodities for all parts of a segment. It is recognized that on some segments it is not practical to use the same tow size for the entire length of a segment. However, the level of detail used was sufficient for NWS study objectives.

Table D-1

Costing Group Assignments

NWS Reporting Commodity	Costing Group	NWS Industry
I. Farm Products	Dry Bulk	Agriculture
II. Metallic Ores	Dry Bulk	Steel
III. Coal	Dry Bulk	Coal
IV. Crude Petroleum	Liquid Bulk	Petroleum
V. Nonmetallic Ores	Other	Other
VI. Food and Kindred Products	Dry Bulk	Agriculture
VII. Lumber and Wood Products	Dry Bulk	Forest Products
VIII. Pulp, Paper and Allied Products	Dry Bulk	Forest Products
IX. Chemicals	Liquid Bulk	Fertilizers and Chemicals
X. Petroleum and Coal Products	Liquid Bulk	Petroleum
XI. Stone, Clay, Glass, and Concrete Products	Other	Other
XII. Primary Metal Products	Iron and Steel Products	Steel
XIII. Waste and Scrap	Other	Other
XIV. Other Commodities	Other	Other

Once the data and model were in place for calculating segment level costs, it was necessary to specify a weighting procedure for computing industry and regional averages. A separate set of equations was developed for this purpose.

Thus, the line-haul cost evaluation procedure consists of two major sets of equations, the analysis segment level costing group equations and data, and the averaging equations. These are discussed in turn below.

SEGMENT LEVEL COSTING GROUP CALCULATIONS

(a) Cost Model

The model presented here consists of three equations. It is based on prior work by A. T. Kearney. Procedures developed in Element K-1, Engineering Analysis of Waterways Systems, were also reviewed. The approach presented here can be considered a simplification of the more complex equations presented in Element K-1.

The three equations used are a fuel cost equation, a tow boat cost equation, and a ton-mile cost equation. Where self-propelled vessels were used as the basis for costing, the same equations were used with tow size set equal to one and barge cost set equal to zero. The three equations and the variable are shown below:

D-1. $F = I \times G$

D-2. $K_1 = F + N$

D-3. $C = \left[3-2B\right] \left[\frac{K_1}{S} + K_2\right] \left[\frac{R}{V} + D\right] \div \left[L \times R\right]$

C = Cost per ton-mile.

B = Percent loaded by costing group and segment.

K_1 = Tow boat costs per hour by costing group and segment.

K_2 = Barge costs per hour by costing group and segment.

S = Tow size by costing group and segment.

R = Length of segment in miles.

V = Average speed by segment.

D = Lock delays Sum of Average per tow within an analysis segment.

L = Barge lading by costing group and segment.

F = Fuel cost per hour

G = Gallons[1] of fuel consumed per hour.

I = Fuel cost index in dollars per gallon[2] consumed per hour.

N = Nonfuel towboat cost per hour

(b) Data

The fuel cost index (I) was developed for three classes of line-haul cost calculations; (1) inland shallow draft subject to PL 95-502 fuel taxes, (2) inland shallow draft not subject to PL 95-502 fuel taxes, and (3) deep draft. The values for these three indexes which were applied to fuel consumption (or aggregate fuel cost in the case of deep draft) are shown in Table D-2 below.

Table D-2

Fuel Cost Indexes

Calculation Class	Year 1977	1980	1985	1990	1995	2000	2003
Inland Subject to Tax	0.742	0.836	1.056	1.240	1.440	1.675	1.835
Inland Not Subject to Tax	0.742	0.826	0.970	1.140	1.340	1.575	1.735
Deep Draft	1.000	1.113	1.307	1.536	1.806	2.122	2.338

1 Unit of measure for deep draft for this variable is total fuel cost.

2 For deep draft this variable is used as a pure index with no unit of measure.

The fuel cost indexes incorporate the effects of three factors. The real cost of fuel was escalated at a compound rate of four percent per year. Fleet average fuel efficiency gains of 0.5 percent per year were also incorporated into this index. Finally PL 95-502 fuel taxes were incorporated where appropriate.

Two variables for this model (equation D-3) are taken from internal calculations within the computer. These are the percent loaded (B) and the delays (D). Percents loaded were set at 50 percent for liquid bulk and other commodities. Upbound and downbound movements of dry bulk and iron and steel products were matched internally in the computer, and future percents projected.

The treatment of delays can only be understood in the context of total transit times and the use of average speeds. The average speed used are less than the maximum underway speeds attainable on most segments. The numbers used reflect upbound and downbound averages taking into account delays as they existed during the base period.

Rather than attempt to sort out origin-destination traffic densities and calculate line-haul costs between locks or by using a complicated weighting scheme, a simpler approach was used. Costs were computed as if each ton travelled the entire length of the segment. Delays were accumulated for each lock for only the traffic using the lock. All averaged delays per tow for all locks were then added to the total transit time for traveling the entire length. This approach was considered acceptable since the intent was to capture the segment level effects of actions. If the purpose had been to calculate costs of specific movements, as would be appropriate for a project level lock analysis, then a more detailed approach attributing specific delays to specific traffic would be necessary.

The line-haul costs on the Great Lakes were also computed on a fixed trip length. The mileage used is essentially the distance (in statute miles) from one end of a lake to the other. While this clearly overstates average trip length, many major ports are at the ends of the lakes (e.g., Duluth, Chicago, Buffalo).

All of the other variables used in the model above were fixed over time for each costing group and analysis segment. The data are presented in Table D-6 of this appendix. Additional discussion of these data items is presented below.

Non-fuel costs of towboats and vessels differed by tow or vessel size and by segment. The values used for tow and vessel sizes for analysis segments for which line-haul costs were computed are presented in the Table D-6.

Barge costs per hour differ by type of commodity and segment. Barge ladings are also presented in the accompanying table by analytical segment. To a certain extent barge sizes and their associated costs had to be tailored to fit the available data. The most prominent example in this appendix is the very large barge size used for liquid bulk commodities. In fact there is a wide variance in sizes of tank barges used. The large barge size used is compensated for in the tow size for these commodities. The basic objective is to capture a "carrying capacity" and associated costs typical of the type of operation. Barge size per se, when treated in this manner, is less important because the dollar cost per ton of carrying capacity for the same type of barge does not vary greatly across barge size.

(c) Examples of Calculations

To illustrate the operation of the model at the analysis segment level, the calculation of line haul costs for the year 1977 and the year 2003 for dry bulk commodities for Analysis Segment 4 (Lower Middle Mississippi) is shown below for the Baseline Scenario for the Present System.

Fuel Cost in 1977 = 0.742 x 199.04

Towboat Cost in 1977 = 147.68768 + 156.21

Line-haul Cost in 1977 = (3-2x.61)((303.90/25)+4.6) ((355/6)+0)/(1,500x355) = 0.0033

Fuel Cost in 2003 = 1.835 x 199.04

Towboat Cost in 2003 = 365.2384 + 156.21

Line-haul Cost in 2003 = (3-2x.59)((365.24/25)+4.6) ((355/6)+0)/(1,500x355) = 0.0051

Additional examples are shown in Table D-3 to illustrate the effects of changes in the components of the fuel cost index compared to delays combined with backhaul (percent loaded) changes generated internally inside the computer.

This table shows the percentage composition of all the changes influencing the year 2003 projected cost compared to the base year. The year 2003 cost is the product of all these changes. As can be seen, the forecast of real fuel cost increases dominates the results, followed by delays combined with changes in backhauls. The first example in Table D-3 corresponds to the example developed earlier. Although the data in Table D-3 are for the High Use Scenario, the results are virtually the same at this level of calculation as for the Baseline Scenario, since there are no lock delays. The only factor that is different for the example of the Dry Bulk calculations for Analysis Segment 4 across scenarios is the percent loaded in the year 2003.

REGIONAL AVERAGE LINE-HAUL COST CALCULATIONS

The calculation of regional averages took place in two steps. First industry averages were computed at the regional level based on weighting segment level costing group results. Second, overall regional averages were computed based on regional level industry results. The weights used were the tons handled. Ton-miles were considered as a weight, but tons were selected since ton-mile projections had not been developed for all analysis segments. The example calculations are shown in Table D-4 below.

Table D-4 shows calculations for only two industries for Region 3. These two sets of calculations are sufficient to illustrate the operation of the methodology. First of all it should be noted that the values for the segment level costing group calculations are the same for all three segments in this region. Thus a single unweighted line-haul cost can be applied to all traffic assigned to the costing group in the region.

If the segments within a region had different tow sizes, ladings, etc., then unique values for each analysis segment would be generated. Instead a single number for farm products under reference column 8 in Table D-4, three columns of figures would be necessary, one for each analysis segment.

Second it should be pointed out that the assignment of reporting commodities to costing groups and industries (shown in Table D-1) is such that each industry has a unique costing group assignment, except for the steel industry. Thus, in regions such as Region 3, where data (including delays and backhaul) are the same for all analysis segments in the region for the same costing group, the regional industry weighted average will always work out to be the same as the unweighted analysis segment result.

In the example shown in Table D-4, the values under reference columns 9, 10, and 11 are the products of the tons accommodated multiplied by the unweighted line-haul cost. It should be pointed out that the weighting procedure results in through tonnages and tonnages moving between segments in the same region being counted more than once. This does not distort the result, rather it enhances the result since longer haul moves are given greater weight.

The final value for the weighted regional industry average is the sum of all the weighted products divided by the sum of all the tons accommodated weights.

Table D-3

Examples of Factors Affecting Increase in Line-Haul Cost
(High Use Scenario Under Present System)

Example	NWS Region	NWS Segment	1977 Base Year Cost	Real Fuel Cost	Fuel Efficiency	Fuel Tax (1)	Delays and Backhaul (2)	2003 Projected Cost (3)
1	3. Lower Mississippi	4. Lower Middle Mississippi	0.0033	58%	-4%	5%	-1%	0.0052
2	4. Baton Rouge to Gulf	7. Baton Rouge to New Orleans	0.0033	58%	-4%	NA	0%	0.0059
3	7. Ohio River	12. Middle Ohio	0.0045	47%	-3%	4%	-18%	0.0055
4	1. Upper Mississippi	1. Upper Mississippi	0.0053	50%	-3%	4%	15%	0.0092

NOTES: (1) PL 95-502 Tax in 2003.

(2) Combined Effect of Delays and Changes in Backhaul.

(3) 1977 dollars.

Table D-4

Example Regional Level Industry Line-Haul Cost Calculations
(Baseline Scenario, Region 3, 1977)

1	2	3	4	5	6	7	8	9	10	11	12	13
		Tons Accommodated By Analysis Segment						Weighted Products By Analysis Segment				
Industry	Commodity Group	4	5	6	Subtotal	Costing Group	Unweighted Line-Haul Cost	4	5	6	Subtotal	Weighted Average Industry Line-Haul Cost
Agriculture	Farm Products	36,510,112	38,237,131	38,235,850	112,983,093	Dry Bulk	0.0033	120,483	126,183	126,179	372,844	
	Food and Kindred Products	7,242,456	7,666,015	7,643,976	22,552,447	Dry Bulk	0.0033	23,900	25,298	25,225	74,423	
	Subtotal	43,752,568	45,903,146	46,879,826	135,535,540			144,383	151,481	151,403	447,267	0.0033
Steel	Metallic Ores	1,755,532	2,505,755	2,496,193	6,757,480	Dry Bulk	0.033	5,793	8,263	8,237	22,299	
	Primary Metal Products	3,940,203	3,980,621	3,741,014	11,661,838	Iron and Steel Products	0.0050	19,701	19,101	18,705	58,309	
	Subtotal	5,695,735	6,486,376	6,237,207	18,419,318			25,494	20,172	26,342	80,608	0.0044

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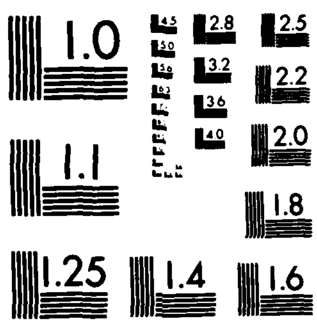

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The steel industry calculations for Region 3 are shown in Table D-4 because this is the only industry identified with more than one costing group. Accordingly, the weighted products are the result of multiplying tons accommodated for specific reporting commodities by specific unweighted costs, rather than the same unweighted cost.

The regional average linehaul cost for all commodities is based on the regional industry averages as shown in Table D-5.

The procedure for computing the overall regional average is rather straight forward. The industry line-haul costs are multiplied by the corresponding tonnages and these products are summed. The sum of these products is then divided by the sum of all the tons accommodated.

Table D-5

Example of Regional Average
Line-Haul Cost Calculations
(Baseline Scenario, Region 3, 1977)

Industry	Industry Regional Average Line-Haul Cost	Millions of Tons Accommodated	Weighted Products
Agriculture	0.0033	46.4	0.153120
Fertilizer & Chemicals	0.0053	14.9	0.078970
Steel	0.0044	6.7	0.029480
Coal	0.0033	11.9	0.039270
Petroleum	0.0053	27.9	0.147870
Forest Products	0.0033	0.9	0.002970
Other	0.0117	14.8	0.173160
TOTAL		123.5	0.624840

Weighted Regional
Average Line-Haul Cost = 0.624840/123,500,000 = 0.0051

NOTE: All the values used in this table were extracted directly from regional evaluation printouts.

LINE-HAUL COST DATA

The remainder of this appendix contains the basic data used for computing line-haul costs. Neither the lock delays, the changes in percent loaded, nor the tonnage weights are shown since no permanent record was produced of all these items. The data is contained in Table D-6 beginning on the next page.

Table D-6

Data For Costing of Domestic Waterborne Line-Haul Operations

NWS Region	NWS Segment	Vessel/Barge Lading in Tons: Dry Bulk	Steel Products	Liquid Bulk	Other	Tow Size (1): Dry Bulk	Steel Products	Liquid Bulk	Other	Vessel/Towboat Fuel Consumption In Gallons/Hour (2): Dry Bulk	Steel Products	Liquid Bulk	Other	Speed (MPH) (3)	Route Miles
Upper Mississippi	Upper Mississippi	1,500	1,000	2,750	1,400	13	13	4	2	100	100	47	37	4	643
Lower Upper Mississippi	Lower Upper Mississippi	1,500	1,000	2,750	1,400	13	13	4	2	100	100	47	37	4	23
	Middle Mississippi	1,500	1,000	2,750	1,400	13	13	6	2	100	100	47	37	4	195
Lower Mississippi	Lower Middle Mississippi	1,500	1,000	2,750	1,400	25	25	12	4	199	199	199	93	6	355
	Upper Lower Mississippi	1,500	1,000	2,750	1,400	25	25	12	4	199	199	199	93	6	295
	Old River to Baton Rouge	1,500	1,000	2,750	1,400	25	25	12	4	199	199	199	99	6	51
Baton Rouge To Gulf	Baton Rouge to New Orleans	1,500	1,000	2,750	1,400	25	25	12	4	199	199	199	93	6	126
	New Orleans to Gulf	1,500	1,000	2,750	1,400	25	25	12	4	199	199	199	93	6	127
	Ouachita Black and Red Rivers	1,500	1,400	2,750	1,200	4	4	2	2	47	47	47	37	4	336
	Old and Atchafalaya River	1,500	1,400	2,750	1,200	4	4	3	2	68	68	68	37	4	146
	Morgan City Bypass	1,500	1,400	2,750	1,400	4	4	3	2	62	62	62	17	4.5	64
Illinois Waterway	Illinois Waterway	1,500	1,000	2,750	1,400	12	8	4	2	47	47	47	37	4	327
Missouri River	Missouri River	1,200	1,000	2,200	1,200	6	6	2	2	100	100	100	37	4.4	753
Ohio River	Upper Ohio	1,500	1,000	2,750	1,400	13	15	3	2	93	93	93	37	4.5	266
	Middle Ohio	1,500	1,000	2,750	1,400	14	15	6	2	93	93	93	37	4.5	280
	Lower Ohio -- Three	1,500	1,000	2,750	1,400	13	15	6	2	78	78	78	37	4.5	239
	Lower Ohio -- Two	1,500	1,000	2,750	1,400	14	15	8	2	109	109	109	37	4.5	150

Table D-6

Data For Costing of Domestic Waterborne Line-Haul Operations

		Vessel/Towboat Non-Fuel Cost in $/Hour				Barge Cost in $/Hour (4)			
NWS Region	NWS Segment	Dry Bulk	Steel Products	Liquid Bulk	Other	Dry Bulk	Steel Products	Liquid Bulk	Other
Upper Mississippi	Upper Mississippi	109	109	62	54	4.60	4.60	18.00	4.60
Lower Upper Mississippi	Lower Upper Mississippi	109	109	62	54	4.60	4.60	18.00	4.60
	Middle Mississippi	109	109	109	54	4.60	4.60	18.00	4.60
Lower Mississippi	Lower Middle Mississippi	156	156	156	109	4.60	4.60	18.00	4.60
	Upper Lower Mississippi	156	156	156	109	4.60	4.60	18.00	4.60
	Old River to Baton Rouge	156	156	156	109	4.60	4.60	18.00	4.60
Baton Rouge To Gulf	Baton Rouge to New Orleans	156	156	156	109	4.60	4.60	18.00	4.60
	New Orleans to Gulf	156	156	156	109	4.60	4.60	18.00	4.60
	Ouachita Black and Red Rivers	62	62	62	54	4.60	4.60	18.00	4.60
	Old and Atchafalaya River	93	93	93	54	4.60	4.60	18.00	4.60
	Morgan City Bypass	78	78	78	54	4.60	4.60	18.00	4.60
Illinois Waterway	Illinois Waterway	62	62	62	54	4.60	4.60	18.00	4.60
Missouri River	Missouri River	109	109	109	54	4.60	4.60	18.00	4.60
Ohio River	Upper Ohio	109	109	109	54	4.60	4.60	18.00	4.60
	Middle Ohio	109	109	109	54	4.60	4.60	18.00	4.60
	Lower Ohio -- Three	93	93	93	54	4.60	4.60	18.00	4.60
	Lower Ohio -- Two	116	116	116	54	4.60	4.60	18.00	4.60

Table D-6

Data For Costing of Domestic Waterborne Line-Haul Operations

NWS Region	NWS Segment	Vessel/Barge Lading in Tons: Dry Bulk	Steel Products	Liquid Bulk	Other	Tow Size (1): Dry Bulk	Steel Products	Liquid Bulk	Other	Vessel/Towboat Fuel Consumption In Gallons/Hour (2): Dry Bulk	Steel Products	Liquid Bulk	Other	Speed (3) (MPH)	Route Miles
Ohio River (Cont'd)	Lower Ohio -- One	1,500	1,500	2,750	1,400	14	15	8	2	156	156	156	37	4.5	45
	Monongahela	900	900	900	700	6	6	4	3	37	37	37	37	4	129
	Allegheny	900	900	900	700	5	6	3	3	37	37	37	37	4	70
	Kanawha	900	900	900	400	9	6	3	3	81	81	81	37	3	90
	Kentucky	900	900	900	650	4	4	3	2	37	37	37	37	4	255
	Green	1,500	1,400	2,750	650	4	4	3	2	37	37	37	37	4	103
	Cumberland	1,500	1,400	2,750	1,200	13	6	2	2	56	56	56	37	4	381
Tennessee River	Upper Tennessee	1,500	1,400	2,750	1,200	10	10	2	2	56	56	56	37	4.3	437
	Lower Tennessee	1,500	1,400	2,750	1,200	12	12	4	2	100	100	100	37	4.3	215
Arkansas River	Arkansas River	1,500	1,400	2,750	1,200	6	4	2	2	62	62	62	37	4	448
Gulf Coast West	GIWW West One	1,500	1,400	2,750	1,300	4	4	3	2	56	56	56	56	4.5	255
	GIWW West Two	1,500	1,400	2,750	1,400	4	4	3	2	56	56	56	56	4.5	322
	GIWW West Three	1,500	1,400	2,750	1,400	4	4	3	2	56	56	56	56	4.5	153
	Houston Ship Channel	1,500	1,400	2,750	1,400	4	4	3	2	56	56	56	56	4.5	51
Gulf Coast East	GIWW East One	1,500	1,400	2,750	900	4	4	2	3	56	56	56	56	4	159
	GIWW East Two	1,500	1,400	2,750	1,400	4	4	2	3	56	56	56	56	4	189
	Florida Gulf Coast	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	Apalachicola, Chattahoochee, Flint Rivers	900	900	900	900	4	4	1							261
Mobile River and Tributaries	Mobile Harbor-	1,400	1,400	2,500	1,400	6	4	2	4	50	50	50	50	4	430
	Alabama Coosa	1,400	1,400	2,500	900	4	4	2	4	50	50	50	50	4	330
	Tennessee-Tombigbee	1,400	1,400	2,500	900	8	8	4	4	56	56	56	56	4.3	232
South Atlantic Coast	Florida/Georgia Coast	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	Carolina Coast	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
Middle Atlantic Coast	Chesapeake and Delaware Bays	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	New Jersey/ New York Coast	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA

Table D-6

Data For Costing of Domestic Waterborne Line-Haul Operations

		Vessel/Towboat Non-Fuel Cost in $/Hour				Barge Cost in $/Hour (4)			
NWS Region	NWS Segment	Dry Bulk	Steel Products	Liquid Bulk	Other	Dry Bulk	Steel Products	Liquid Bulk	Other
Ohio River (Cont'd)	Lower Ohio -- One	137	137	137	54	4.60	4.60	18.00	4.60
	Monongahela	54	54	54	54	3.40	3.40	7.60	3.40
	Allegheny	54	54	54	54	3.40	3.40	7.60	3.40
	Kanawha	93	93	93	93	3.40	3.40	7.60	3.40
	Kentucky	54	54	54	54	3.40	4.60	3.40	3.40
	Green	54	54	54	54	4.60	4.60	18.00	3.40
	Cumberland	78	78	78	54	4.60	4.60	18.00	4.60
Tennessee River	Upper Tennessee	78	78	78	54	4.60	4.60	18.00	4.60
	Lower Tennessee	109	109	109	54	4.60	4.60	18.00	4.60
Arkansas River	Arkansas River	78	78	78	54	4.60	4.60	18.00	4.60
Gulf Coast West	GIWW West One	78	78	78	78	4.60	4.60	18.00	4.60
	GIWW West Two	78	78	78	78	4.60	4.60	18.00	4.60
	GIWW West Three	78	78	78	78	4.60	4.60	18.00	4.60
	Houston Ship Channel	78	78	78	78	4.60	4.60	18.00	4.60
Gulf Coast East	GIWW East One	78	78	78	78	4.60	4.60	18.00	4.60
	GIWW East Two	78	78	78	78	4.60	4.60	18.00	4.60
	Florida Gulf Coast	491	491	598	491	-	-	-	-
	Apalachicola, Chattahoochee, Flint Rivers	62	62	62	62	3.40	3.40	7.60	3.40
Mobile River and Tributaries	Black Warrior-Mobile Harbor	62	62	62	62	4.60	4.60	18.00	4.60
	Alabama Coosa	62	62	62	62	4.60	4.60	18.00	3.40
	Tennessee-Tombigbee	78	78	78	78	4.60	4.60	18.00	3.40
South Atlantic Coast	Florida/Georgia Coast	491	491	598	491	-	-	-	-
	Carolina Coast	491	491	598	491	-	-	-	-
Middle Atlantic Coast	Chesapeake and Delaware Bays	491	491	598	491	-	-	-	-
	New Jersey/New York Coast	491	491	598	491	-	-	-	-

Table D-6

Data For Costing of Domestic Waterborne Line-Haul Operations

NWS Region	NWS Segment	Vessel/Barge Lading in Tons: Dry Bulk	Steel Products	Liquid Bulk	Other	Tow Size (1): Dry Bulk	Steel Products	Liquid Bulk	Other	Vessel/Towboat Fuel Consumption In Gallons/Hour (2): Dry Bulk	Steel Products	Liquid Bulk	Other	Speed (MPH) (3)	Route Miles
North Atlantic Coast	North Atlantic Coast	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
Great Lakes, St. Lawrence Seaway, New York State Waterways	New York State Waterways	3,000	3,000	3,000	3,000	1	1	1	1	31	31	31	31	3	300
	Lake Ontario and St. Lawrence	20,000	20,000	20,000	20,000	NA	NA	NA	NA	NA	NA	NA	NA	15	554
	Lake Erie	45,000	20,000	20,000	20,000	NA	NA	NA	NA	NA	NA	NA	NA	15	244
	Lake Huron	45,000	20,000	20,000	20,000	NA	NA	NA	NA	NA	NA	NA	NA	15	371
	Lake Michigan	45,000	20,000	20,000	20,000	NA	NA	NA	NA	NA	NA	NA	NA	15	336
	Lake Superior	45,000	20,000	20,000	20,000	NA	NA	NA	NA	NA	NA	NA	NA	15	394
Washington/ Oregon Coast	Puget Sound	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	Oregon/ Washington Coast	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
Columbia - Snake Waterway	Upper Columbia - Snake	3,000	3,000	2,200	1,000	5	5	5	8	81	81	81	81	4	171
	Lower Columbia - Snake	3,000	3,000	2,200	1,000	5	5	5	8	81	81	81	81	4	146
California Coast	Northern California	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	San Francisco Bay Area	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	Central/South California	32,000	14,000	90,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
Alaska	Southeast Alaska	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	South Central Alaska Coast	32,000	14,000	125,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
	West and North Coasts of Alaska	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
Hawaii and Pacific	Hawaii and Pacific Territories	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
Caribbean	Caribbean	32,000	14,000	55,000	32,000	NA	NA	NA	NA	NA	NA	NA	NA	15	NA

Table D-6

Data For Costing of Domestic Waterborne Line-Haul Operations

		Vessel/Towboat Non-Fuel Cost in $/Hour				Barge Cost in $/Hour (4)			
NWS Region	NWS Segment	Dry Bulk	Steel Products	Liquid Bulk	Other	Dry Bulk	Steel Products	Liquid Bulk	Other
North Atlantic Coast	North Atlantic Coast	491	491	598	491	-	-	-	-
Great Lakes, St. Lawrence Seaway, New York State Waterways	New York State Waterways	54	54	54	54	9.20	8.10	15.20	9.20
	Lake Ontario and St. Lawrence	451	451	533	451	-	-	-	-
	Lake Erie	451	451	533	451	-	-	-	-
	Lake Huron	451	451	533	451	-	-	-	-
	Lake Michigan	451	451	533	451	-	-	-	-
	Lake Superior	451	451	533	451	-	-	-	-
Washington/ Oregon Coast	Puget Sound	491	491	598	491	-	-	-	-
	Oregon/ Washington Coast	491	491	598	491	-	-	-	-
Columbia - Snake Waterway	Upper Columbia - Snake	93	93	93	93	9.20	8.10	12.00	3.90
	Lower Columbia - Snake	93	93	93	93	9.20	8.10	12.00	3.90
California Coast	Northern California	491	491	598	491	-	-	-	-
	San Francisco Bay Area	491	491	598	491	-	-	-	-
	Central/South California	491	491	598	491	-	-	-	-
Alaska	Southeast Alaska	491	491	598	491	-	-	-	-
	South Central Alaska Coast	491	491	598	491	-	-	-	-
	West and North Coasts of Alaska	491	491	598	491	-	-	-	-
Hawaii and Pacific	Hawaii and Pacific Territories	491	491	598	491	-	-	-	-
Caribbean	Caribbean	491	491	598	491	-	-	-	-

NOTES: (1) Tow sizes are not applicable for self propelled vessels. In order to ensure proper operations of the computer programs tow sizes were set equal to **One** for self propelled vessels.

(2) For self propelled vessels the figures shown are base year fuel costs, not consumption.

(3) More precise estimates of some of these speeds can be found in a special corps study, Vessel Characteristics Survey, finalized during the latter stages of NWS integration.

(4) Barge cost is zero for self propelled vessel operations.

SOURCES:

1. Prior NWS work in Elements D and K1.
2. Appendix A of An Evaluation of the Transportation Economics of the Tennessee-Tombigbee Waterway prepared by A.T. Kearney for the Mobile District of the Corps of Engineers.
3. Letter transmitting "Towboat and Barge Operating Costs on the Mississippi River System," DAEN-CWP-S.
4. Maritime Administration, Operating Costs of U.S. Flag Vessels.
5. Interviews with Carriers and Lockmasters.

APPENDIX E

SENSITIVITY ANALYSIS OF LOCK CAPACITY ESTIMATES

APPENDIX E

SENSITIVITY ANALYSIS OF LOCK CAPACITY ESTIMATES

INTRODUCTION

A series of models was developed to estimate lock capacity and determine the impacts of physical shortfalls in lock capacity on projected usage. These models include:

1. Models to estimate changes in traffic data at the lock level from 1980 to 2003.

2. A lock capacity model that is capable of incorporating changes in the traffic mix at locks over time and the effects of generally applicable non-structural actions.

3. A model to determine the effect of a physical shortfall in capacity at one lock on the traffic level at other locks in the system.

The lock capacity model was designed to incorporate the effects of widely applicable actions on lock capacity. These widely applicable actions include:

1. Extension of guidewalls and employment of extra towboats or winches to eliminate the additional chamber time lost to the making and breaking of tows too large to fit within the lock chamber.

2. Implementation of a 4-up and 4-down lock operating policy wherever the time saved in the approach, entry and exit from the chamber is not offset by the additional time caused by turning back the empty chamber.

3. Change in lock operating policies to minimize any conflicts with recreational use of lock chambers at the expense of commercial navigation.

This appendix contains sensitivity analyses of lock capacity estimates at various sites under relaxed conditions different from those imposed above and where unique site characteristics require further analysis.

MINOR STRUCTURAL ACTIONS

Some minor structural actions above and beyond these widely applicable actions may be appropriate for some locks with unique configurations. A sensitivity analysis was performed to determine if any of our findings should be modified regarding which locks are potentially constraining through the year 2003. The results from examining three of these locks are presented below.

(a) Lock and Dam 22 on the Upper Mississippi

Lock and Dam 22 was originally found to be constraining under three of the four scenarios, assuming that a second 1200' by 110' chamber at Lock and Dam 26 was constructed before the year 2000.

One of the reasons why Lock and Dam 22 appears as a constraining lock before the two locks to either side of it is the unusually long approach and exit times at the site. Savings in exchange approach and exit times might be realized in the upper as well as in the lower approach channels by various measures.

For upper approaches, the approach distance might be reduced from 4,000 feet to approximately 3,000 feet by enlarging the channel to allow for the exchange of two 15 barge tows half a mile from the lock. Dredging would be required to enlarge the channel. Approach and exit times might be reduced by as much as 25 percent. Further savings in approach time might be obtained by reducing outdraft problems through wall extension. This action might reduce approach times by as much as two minutes on an annual basis (outdraft problems are seasonal).

The major problem at the lower pool is caused by an eddy that makes tow alignment difficult along the lower guidewall. The calculated approach speed is only 2.3 feet/second instead of an average approach speed of 5.4 feet/second for upstream tows at other locks on the Mississippi River.

The eddy problem might be solved by extending the lower guidewall. Exchange approach and exit times on the lower approach channel might be reduced by as much as 50 percent. However, the seasonal aspect of this eddy problem is such that average annual timings would only be reduced by approximately 25%.[1]

As a result of these three actions, lock capacity might be increased approximately 10% more than the original lock capacity calculation. This would change the conclusion about this lock as a constraint only under the baseline and high use scenarios. In both of these cases, the additional capacity would be adequate to handle projected usage through the year 2003. (No change in conclusion is made if a second chamber is not built at Lock and Dam 26.) The actions, if effective, would have the effect of delaying the need for a new chamber for approximately five years.

(b) Marseilles Lock and Dam on the Illinois River

Marseilles was also originally found to be constraining if another chamber is built at Lock and Dam 26 before the year 2000. In this case, Marseilles was found to be constraining under all four scenarios.

There are at least two reasons why lock capacity might be increased at Marseilles above and beyond the levels indicated in the original calculation. First, the upper approach distances might be shortened from over 10,000 feet to 4,000 feet if the channel is enlarged at a location some 4,000 feet from the lock and running some

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1 Because of the site configuration, including bank, channel, lock, and dam, there is a trade-off between outdraft and eddy problems. If the gate openings at the dam are such that outdraft is reduced in the upper pool, then the eddy is increased in the lower pool, and vice versa.

2,000 feet in distance. The estimated savings in time would be approximately two minutes for the lock approach as well as exit.

In addition, the filling time at Marseilles is unusually long. There are two explanations for this long filling time:

1. The lock operators do not fill the chamber faster, to avoid air entrainment in conduits due to the high lift (25 feet).

2. Debris often obstructs the intakes. The intake screens are cleaned by using buckets. This operation is conducted very infrequently when filling time starts to exceed 30 minutes.

Two minor structural measures might possibly be implemented at Marseilles to solve these problems:

1. Drill air holes to allow the highly compressed air entrained in the conduits to escape.

2. Install mechanical trash rakes.

Filling time might be reduced from a yearly average of 26 minutes to as little as 18 minutes.

Chambering time would in turn be reduced from 20 minutes to 16 minutes. This four minute decrease in chambering time along with the improvements to approach times would be sufficient to prevent Marseilles from being a constraining lock under all four scenarios. The increase in capacity, if the measures would be effective, would be sufficient to delay the need for a new chamber for at least five years.

(c) The Great Lakes/ St. Lawrence Seaway System Locks

Five of the eight locks at the Welland Canal section of the St. Lawrence Seaway were originally found to be constraining under three of the four scenarios and within

a fraction of being considered constraining under the low use scenario.[2]

Two actions may be appropriate at these locks. However, the actions must still be considered somewhat speculative at the present time until demonstrations and testing are undertaken.

These actions are:

1. Implementing a computerized monitoring system for scheduling and processing of vessels.

2. Utilizing specifically designed tugs or shunters in combination with precise guidance systems for decreasing lockage times.

Preliminary studies indicate that a computerized monitoring system at the Welland Canal section could increase capacity from 5% to 10%. Such studies also indicate that a 20% to 25% savings in total lockage time, which corresponds to a 25% to 30% increase in capacity, might be realized.

If such actions were to be effective at the Welland Canal section of the St. Lawrence Seaway the conclusion about these locks being constraining would change. It should be emphasized, however, that the entire savings of these actions would have to be realized if there were to be a change in the original conclusions under the bad energy and high use scenarios.

The St. Lawrence River section of the Seaway was also originally found to be constraining under the high use scenario if additional capacity was provided at five of the Welland Canal locks before the year 2000. Both the computerized monitoring system and marine shunters may be applicable to these locks as well.

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2 The other three locks at the Welland Canal have dual chambers.

RECREATIONAL USAGE OF COMMERCIAL LOCKS

Recreational craft also use the commercial navigation system, including locks. The lock time use solely by these vessels is not available to commercial traffic. The modified equation shown in Appendix C simply deleted recreational usage in accordance with the imposition of one or more nonstructural actions. The question was raised in the November meetings about the effect of this action on study conclusions. Table E-1 presents the results of a sensitivity analysis of this issue for selected locks.

The locks selected for analysis are in areas of significant recreational use combined with a relative absence of auxiliary chambers. Thus recreational use is a more important issue for these locks. The data analyzed were for the High Use Scenario in the year 2003 only.

The first step in the sensitivity analysis was to compute the effect on capacity of allowing the same level of exclusive recreational usage as was reported in the base year data. The percentage reduction in capacity is shown. The second step was to test the reduced capacity against projected usage to see if the locks became constrained. The final step was to compare conclusions of the sensitivity analysis with the basic conclusions incorporating the non-structural action. The result was that all the locks which were constrained under the sensitivity analysis were also found to be constrained under the basic calculations. No additional locks were found to be constrained. Therefore the study conclusions remain unchanged.

RESTRICTED NAVIGATION SEASONS

Locks in three NWS regions have navigation seasons that are restricted to less than a full year. This in turn restricts the maximum potential throughout capacity of these locks. These locks were analyzed further and the results are shown in Table E-2.

Table E-1

Sensitivity Analysis of Recreational Usage of Selected Locks

NWS Region	NWS Segment	River/ Waterway	Lock Name	Percent Reduction in Capacity	Would Lock Be Constrained?	Is Conclusion Different?
Upper Mississippi	Upper Mississippi	Mississippi R., Minneapolis to mouth of Illinois R.	L&D 25	3	No	No
			L&D 24	3	No	No
			L&D 22	4	Yes	No
			L&D 21	3	No	No
			L&D 20	3	No	No
			L&D 19	7	No	No
			L&D 18	3	No	No
			L&D 17	3	No	No
			L&D 16	3	No	No
			L&D 15 Main	3	No	No
			L&D 15 Auxiliary	12	No	No
			L&D 14 Main	7	No	No
			L&D 14 Auxiliary	3	No	No
			L&D 13	13	No	No
			L&D 12	13	No	No
			L&D 11	13	No	No
			L&D 10	13	No	No
			L&D 9	13	No	No
			L&D 8	13	No	No
			L&D 7	13	No	No
			L&D 6	13	No	No
			L&D 5A	13	No	No
			L&D 5	13	No	No
			L&D 4	13	No	No
			L&D 3	13	No	No
			L&D 2	15	No	No
			L&D 1	13	No	No
			L&D 1	13	No	No
			Lower St.	13	No	No
			Anthony	13	No	No
Lower Upper Mississippi	Lower Upper Mississippi	Mississippi R., Illinois R. to Missouri R.	L&D 26 Main	5	Yes	No
			L&D 26 Auxiliary	24	Yes	No
	Middle Mississippi	Mississippi R., Missouri R. to Ohio R. (Chain of Rocks Canal)	L&D 27 Main	6	No	No
			L&D 27 Auxiliary	22	No	No
Illinois River	Illinois Waterway	Illinois R.	LaGrange	5	Yes	No
			Peoria	5	Yes	No
			Starved Rock	5	No[1]	No
			Marseilles	6	Yes	No
			Dresden Island	5	No	No
		Des Plaines R.	Brandon Road	5	No	No
		Chicago Sanitary and Ship Canal	Lockport	4	No	No
		Calumet R.	T.J. O'Brien	15	No	No

NOTE: (1) Without eliminating the time lost to recreation this lock is within one percentage point of being constrained.

Table E-2

Sensitivity Analysis of Season Extension at Selected Locks

NWS Region	NWS Segment	River/ Waterway	Lock Name	Number of Days Per Year Available	Maximum Potential Percent Increase in Capacity	Is Lock Constrained?	Is Conclusion Different?
Upper Mississippi	Upper Mississippi	Mississippi R., Minneapolis to mouth of Illinois R.	L&D 25	290	21%	No	No
			L&D 24	290	21	No	No
			L&D 22	295	19	No	Yes
			L&D 21	290	21	No	No
			L&D 20	290	21	No	No
Great Lakes St. Lawrence Seaway - New York State Waterways	Lake Ontario and St. Lawrence Seaway	St. Lawrence River	St. Lambert	240	34	No	Yes
			Cote Ste. Catherine	240	34	No	Yes
			Lower Beauharnois	240	34	No	Yes
			Upper Beauharnois	240	34	No	Yes
			Snell	240	34	No	Yes
			Eisenhower	240	34	No	Yes
			Iroquois	240	34	No	Yes
		Welland Canal	1	240	34	No	Yes
			2	240	34	No	Yes
			3	240	34	No	Yes
			4	240	34	No	Yes
			5	240	34	No	Yes
			6	240	34	No	Yes
			7	240	34	No	Yes
			8	240	34	No	Yes
	Lake Huron	St. Mary's R.	New Poe	270	26	No1/	No
			Mac Arthur	270	26	No1/	No

NOTES: (1) Season extension would provide significant relief here under the defense emergency sensitivity, but would not by itself be sufficient to meet the capacity shortfall.

The NWS lock capacity analysis developed in Element K1 (Engineering Analysis of Waterways Systems) treats the effects of navigation seasons linearly. That is, capacity varies directly with season lengths. Thus the potential increases in capacity shown in Table E-2 are simply the results of assuming 100% availability. This approach overstates the potential capacity gains from season extension. The efficiency of both locks and tows or vessels is reduced in winter and this is not captured here. Nevertheless it is useful to review the maximum potential effects of season extensions. The analysis shown in Table E-2 is for the High Use scenario only in the year 2003.

Only one lock, Lock and Dam 22, on the Upper Mississippi was constrained under the basic analysis. Increasing the availability of this lock (without adjusting any other variables) to year round navigation would provide adequate capacity. However, in order for such capacity to be effectively used, seasons at adjacent locks, and many more locks upstream, would also have to be extended. Increasing navigation seasons on the Upper Mississippi would probably not be cost effective in relieving capacity constraints on this NWS segment alone.

Season extension on the Great Lakes and St. Lawrence Seaway on the other hand could be quite effective in increasing lock capacity. The potential increases shown in Table E-2 correspond roughly to the capacity increases estimated in a recent Corps study, although the methodologies are quite different.[3] Although the conclusions about capacity constraints here differ for the Welland Canal and St. Lawrence River sections of the Seaway, it should again be pointed out that this analysis does not take into account reduced operating efficiencies. It is also important to note that, while year round navigation at the Sault Ste. Mary Locks on the St. Mary's River is helpful during the defense emergency analyzed separately, season extension by itself would not be sufficient to meet the capacity shortfall.

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3 United States Army Engineer District, Detroit, Final Survey Study for Great Lakes and St. Lawrence Seaway Navigation Season Extension, Appendix D.

OPEN PASS CONDITIONS

As stated in Appendix C, locks with open pass conditions available 60% or more of the year or more were considered to be non-constraining. The available data indicated that two lock sites were at the bottom end of this range and they are reviewed here.

Calcasieu Lock is on the Gulf Intracoastal Waterway West. The seasonality coefficient for this lock is 1.00, indicating no difference in flows across seasons. If capacity were computed as if the lock had no open pass, it would be 58.8 million tons annually under the High Use Scenario traffic conditions in the year 2003. Projected use under the High Use Scenario in the year 2003 for this lock is 56.8 million tons under the High Use Scenario. Therefore the conclusion about whether or not Calcasieu Lock would constrain traffic is unaffected.

Locks and Dam 52 on the Ohio River also have open pass conditions 60% of the year. If no open pass is assumed, capacity at this facility is estimated to be 91.3 million tons under High Use traffic conditions. Projected Use under the High Use Scenario is forecast to be 136.6 million tons. The seasonality coefficient is computed at .85. Tons not handled at Locks and Dam 52 could be as high as 10 to 20 million tons under this scenario if peak traffic periods correspond to non-open pass periods.

Locks and Dam 53 on the Ohio is open pass approximately 90% of the year. Up until December, 1980, when the new 1,200' x 110' chamber went into operation at this site, capacity could have been severely contrained during drought years. With the new chamber in operation this risk of a shortfall is greatly reduced. It should be noted however that both the 1200' chambers at Locks and Dams 52 and 53 are "temporary" structures with design lives of less than 50 years.

APPENDIX F

ANALYSIS OF OBSOLETE LOCKS

APPENDIX F

ANALYSIS OF OBSOLETE LOCKS

PURPOSE OF APPENDIX

The purpose of this appendix is to present and discuss the analysis of lock obsolescence conducted as part of the evaluation of the present system. This analysis was discussed briefly in the Element L (Evaluation of Alternative Future Strategies for Action) report presented in March of 1981. It has been included as part of the evaluation of the present system in response to comments.

The issue of lock obsolescence was first raised at the public meetings held in the Fall of 1980 and in subsequent review sessions with the Corps of Engineers. A concept was developed, criteria were specified for identification of obsolete locks, and the results incorporated into the analysis of strategies. This appendix provides the complete details of that analysis.

CONCEPT OF OBSOLESCENCE

Many of the locks on the present waterway system are old and/or were designed and constructed to meet water transportation characteristics which were different than those which have materialized over time. For example, some locks were designed based upon a forecast of future tow sizes which turned out to be low. Some of these locks still exist, and adversely affect water transportation.

However, this issue is different from the physical constraints to traffic which some locks pose. Locks may be considered obsolete yet still be adequate to pass physically all the forecasted traffic. Therefore it was considered useful to explore this issue further.

Locks were reviewed with regard to age, utilization, and chamber dimensions in relation to other locks in the

system of which a particular lock is a part. Chambers which are small with respect to existing tow sizes or with respect to neighboring locks can impose additional costs on the private sector due to additional delays or even impose requirements for reconfiguration of tows. Therefore all of the locks in the shallow draft waterway system included in Appendix C of the Element K2 (Evaluation of the Present Navigation System) report were reviewed regarding obsolescence.

CRITERIA USED FOR SCREENING LOCKS

Three criteria were used for screening locks for obsolescence.

(a) Age of Locks

For a lock to be considered obsolete for NWS purposes it had to be thirty years old in 1977. Such locks would be over fifty years old by the end of the time horizon of the National Waterway Study. Such locks incur additional costs for higher levels of rehabilitation over time. Thus savings might be realized by replacing locks under this criterion.

(b) Chamber Dimensions

For locks to be considered obsolete the main chambers had to be less than 110 ft. wide by 600 ft. long or otherwise mismatched with other locks of the system of which they are a part. The fact that a lock that is only 600 ft. long may generate a requirement for performing double lockages on some segments was not considered to be sufficient by itself for classification as obsolete.

(c) Utilization

In order to avoid inclusion of locks with extremely low utilization which might meet the other two criteria, a minimum utilization figure was established. For locks to be considered obsolete they had to have a utilization of 30% under the baseline scenario by the year 2003. Thus locks which clearly meet the first two criteria, such as

all of the locks on the Kentucky River system, would not be included as candidates for potential replacement, due to obsolescence because of their low utilization.

RESULTS OF THE ANALYSIS

All of the locks reviewed under the criteria described above are listed in Table F-1 below. As a result of the application of these criteria to the list of locks in Table F-1, a definitive list of "obsolete" locks was developed. This list consists of the following locks:

1. Lock 1 on the Upper Mississippi River.

2. Locks 3, 4, 7, and 8 on the Monongahela River.

3. Winfield and Marmet Locks on the Kanawha River.

4. Harvey Lock on the Gulf Intracoastal Waterway West.

5. Inner Harbor Navigation Channel Lock on the Gulf Intracoastal Waterway East.

6. Oliver Lock on the Warrior River.

7. Bonneville Lock on the Columbia River.

Table F-1

Locks Screened for Obsolescence

River/Lock[1]	% of Utilization 1977	% of Utilization 2003	Dimensions in Feet Width	Dimensions in Feet Length	Year Built
Allegheny					
All locks[2]	20-	27-	56	360	1938-
Monongahela					
L&D 2	36	52	110	720	1951
L&D 3	51	68	56	720	1907
L&D 4	39	53	56	720	1932
Maxwell (3)	25	34	84	720	1965
L&D 7	35	45	56	360	1926
L&D 8	27	34	56	360	1926
Kanawha					
Winfield (3)	36	44	56	360	1937
Marmet (3)	24	36	54	360	1934
London (3)	7	11	56	360	1934
Green					
L&D 1	29	69	84	600	1956
L&D 2	25	62	84	600	1956
Cumberland					
Barkley	23	40	110	800	1964
Cheatham	10	10	110	800	1959
Old Hickory	2	4	84	400	1957
Cordell Hull	0	0	84	400	1973
Kentucky					
Locks 1 thru 4 (2)	7-	4-	38	145	1844-

Table F-1
(continued)

Lock Screened for Obsolescence

River/Lock(1)	% of Utilization 1977	% of Utilization 2003	Dimensions in Feet Width	Dimensions in Feet Length	Year Built
Tennessee					
Kentucky	40	67	110	600	1944
Pickwick (4)			110	600	1937
Wilson			110	600	1959
Wheeler			110	600	1944
Guntersville			110	600	1962
Nickajack	10	11	110	600	1967
Chickamanga	8	11	60	360	1940
Watts Bar	3	3	60	360	1942
Ft. Loudoun	1	2	60	360	1943
Clinch					
Melton Hill (5)	0+	0+	75	400	1963
Mississippi					
L&D 1 (2)(3)	13	30	56	400	1948(-)
Lower St. Anthony	14	35	56	400	1940
Upper St. Anthony	14	35	56	400	1963
Tombigbee					
Coffeeville			110	600	1961
Demopolis			110	600	1956
Warrior					
Warrior			110	600	1957
Wm. B. Oliver	51	96	95	460	1940
Holt			110	600	1966
Bankhead			110	600	1975

Table F-1
(continued)

Locks Screened for Obsolescence

River/Lock(1)	% of Utilization 1977	2003	Dimensions in Feet Width	Length	Year Built
Alabama					
All locks (5)			84	600	1969+
Pearl					
Locks 1,2,&3 (2)	1-	1-	65	356	1951
Apalachicola					
Jim Woodruff	3	3	82	505	1957
Chattahoochee					
All locks	3-	4-	82	505	1963
Ouachita					
Columbia	2	3	84	600	1972
L&D 6 (2)(7)	1-	1-	55	268	1923
L&D 8 (7)	1	1	55	268	1926
Black					
Jonesville	3	4	84	600	1972
Old River					
Old River	9	10	75	1200	1963
Atchafalaya					
Berwick (8)			45	307	1951

Table F-1
(continued)

Locks Screened for Obsolescence

River/Lock[1]	% of Utilization 1977	% of Utilization 2003	Dimensions in Feet Width	Dimensions in Feet Length	Year Built
Gulf Intra-Coastal Waterway, West					
Harvey	62	83	75	425	1935
Algiers	66	88	75	797	1956
Bayou Sorrel	(9)	(9)	75	800	1952
Port Allen	40	58	84	1198	1961
Bayou Bouef	(9)	(9)	75	1158	1956
Vermilion (10)	(9)	(9)	56	1200	1934
Calcasieu	(9)	(9)	75	1204	1950
Inner Harbor Canal					
Inner Harbor	79	91	75	640	1923
Columbia/Snake					
Bonneville	48	76	76	556	1937
All other locks (2) (5)	15-	24-	86	675	1953+

NOTES: (1) All lock data except utilization is for main chamber unless otherwise noted. Utilization is based on total capacity of all chambers at a site.

(2) Notation of "-" denotes "or less."

(3) Two identical chambers.

(4) New 110' x 600' lock under construction by TVA. Due to be completed in 1985.

(5) Notation of "+" denotes "or more."

Table F-1
(continued)

Locks Screened for Obsolescence

(7) New locks will be constructed by 1990 as part of "present system." Dimensions of new locks are not known.

(8) EP 1105-2-11 lists Berwick on the Atchafalaya. INSA P.E. map and NWS map show Berwick on Bayou Teche.

(9) Open pass a high % of time.

(10) New 110' x 1,200' under construction as part of "present system."

SOURCES: EP 1105-2-11 and integration printouts.

FURTHER CONSIDERATIONS
CONCERNING OBSOLESCENCE

The criteria used for identifying obsolete locks is fairly stringent. It is worth pointing out that some other locks that currently exist may also be considered obsolete if some of the criteria are relaxed. These are discussed in turn.

The existing main chamber at Locks and Dam 26 is 110 ft. by 600 ft. However, immediately downstream, the main chamber of Lock 27 is 110 ft. by 1,200 ft. While all but one of the main chambers of all of the upstream locks are the same size as the main chamber at Locks and Dam 26, the fact remains that Locks and Dam 26 serves a heavy volume of traffic from two major segments. Clearly, the existing facility meets the utilization and age criteria for obsolescence. If the chamber dimension criterion is relaxed somewhat, then Locks and Dam 26 would also be considered obsolete.

The existing chamber of Vermilion Lock on the Gulf Intracoastal Waterway West is narrower than any of the other locks on that system. This narrow chamber width of 56 feet clearly restricts tows to a single barge configuration prohibiting running two barges abreast. To the extent that channel conditions on the Gulf Intracoastal Waterway would permit running larger tows then this single facility constrains tow dimensions and imposes additional costs. If the chamber dimension criterion is relaxed somewhat, then this facility too could be considered obsolete.

There are eighteen locks and dams on the mainstem of the Ohio River. All of these facilities have main chambers with dimensions that are 110 ft. by 1,200 ft. except Emsworth, Dashields, Montgomery, Gallipolis, and Lock and Dam 53. If the chamber dimension criterion is relaxed, then both Gallipolis and Lock and Dam 53 could be considered to be presently obsolete. Gallipolis in particular is a 600 ft. long facility which is bracketed by larger facilities on either side. Lock and Dam 53 is at the very bottom of the system where the largest tows are used and imposes additional costs on users during periods

of time when the lock is in use. Emsworth, Dashields, and Montgomery on the other hand are all at the upper end of the system with somewhat lower utilization and somewhat smaller tow sizes. Relaxation of the chamber criteria in their case would seem to be somewhat less justifiable.

CONCLUSIONS

Clearly, locks which are old, inefficient, and of unusual chamber dimensions may pose problems for the waterways system and yet still not constrain traffic. An enhanced system would logically consider upgrading of these locks based upon a more detailed analysis than that contained here. Age, inefficiency, and unusual chamber dimensions are real problems nevertheless and would logically be part of any comprehensive criteria for detailed project level lock evaluation. The evaluation used here is simple yet identifies clearly obsolete locks in a practical manner.

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